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NATIONAL DAM SAFETY PROGRAM. SWIFT CREEK RESERVOIR DAM (INVENTO--ETC(U)

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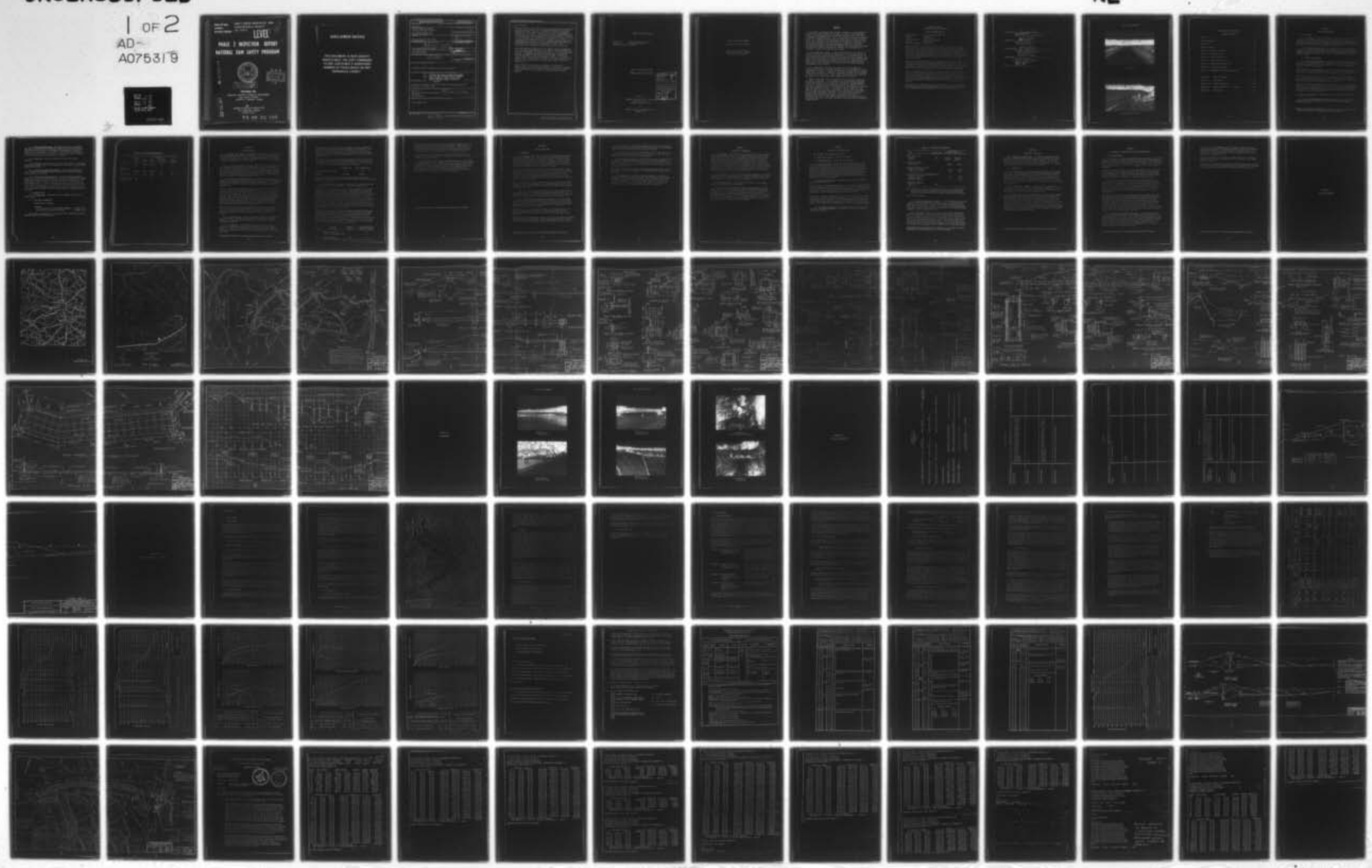

Name Of Dam: SWIFT CREEK RESERVOIR DAM
Location: CHESTERFIELD COUNTY
Inventory Number: VA. 04112

LEVEL II

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

PREPARED FOR

NORFOLK DISTRICT CORPS OF ENGINEERS
803 FRONT STREET
NORFOLK, VIRGINIA 23510

BY

DEWARD M. MARTIN & ASSOCIATES
WILLIAMSBURG, VIRGINIA
AUGUST, 1979

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20. Abstract

Pursuant to Public Law 92-367, Phase I Inspection Reports are prepared under guidance contained in the recommended guidelines for safety inspection of dams, published by the Office of Chief of Engineers, Washington, D. C. 20314. The purpose of a Phase I investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general conditions of the dam is based upon available data and visual inspections. Detailed investigation and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

Based upon the field conditions at the time of the field inspection and all available engineering data, the Phase I report addresses the hydraulic, hydrologic, geologic, geotechnic, and structural aspects of the dam. The engineering techniques employed give a reasonably accurate assessment of the conditions of the dam. It should be realized that certain engineering aspects cannot be fully analyzed during a Phase I inspection. Assessment and remedial measures in the report include the requirements of additional indepth study when necessary.

Phase I reports include project information of the dam and appurtenances, all existing engineering data, operational procedures, hydraulic/hydrologic data of the watershed, dam stability, visual inspection report and an assessment including required remedial measures.

MIDDLE JAMES RIVER BASIN

Name of Dam : Swift Creek Reservoir Dam
Location : Chesterfield County
Inventory Number: VA 04112

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

Prepared for

NORFOLK DISTRICT CORPS OF ENGINEERS
803 Front Street
Norfolk, Virginia 23510

by

Deward M. Martin & Associates, Inc.
August 1979

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

SWIFT CREEK RESERVOIR DAM
CHESTERFIELD COUNTY, VIRGINIA
INVENTORY NO. VA 04112

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of the Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation and analyses involving topographic mapping, subsurface investigations testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established guidelines, the spillway design flood is based on the estimated "Probable Maximum Flood" for the region (flood discharges that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the design flood should not be interpreted as necessarily posing a highly inadequate condition. The design flood provides a measure of relative spillway capacity and serves as an aide in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

BRIEF ASSESSMENT OF DAM

Name of Dam:	Swift Creek Reservoir Dam
State:	Virginia
County:	Chesterfield
USGS Quad Sheet:	Hallsboro, Virginia
Stream:	Swift Creek
Date of Inspection:	June 25, 1979

Swift Creek Dam is an earthfill structure about 1,110 feet long and 37.5 feet high. The dam is owned and operated by Chesterfield County. The dam is classified as intermediate in size with a high hazard classification. The dam has a 400-foot concrete spillway (Appendix I, Plate No. 3) with a crest elevation of 177.0 feet m.s.l. A water intake tower is located within the reservoir to drain water from the lake to be used at the Swift Creek water treatment plant or to lower the water level in the lake.

Based on criteria established by the Department of the Army, Office of the Chief of Engineers, the Spillway Design Flood is the PMF. The spillway will pass 60% of the PMF without overtopping the dam. The SDF will overtop the dam by 3.2 feet with an average critical velocity of 1.9 feet per second. The spillway is therefore adjudged inadequate.

It is recommended that the owner, at his own expense, secure the services of a professional engineer to determine whether the core is functioning properly and this effect on the present stability of the dam. The owner should further investigate the seepage noted in Section 3 and determine remedial measures to be implemented, i.e. detail repairs to the spillway, sealer joints and the erosion repairs and reseeding.

The schedule for completion of remedial work which may result from the investigation should be in agreement with the Commonwealth of Virginia for a reasonable time frame when all measures will be completed.

Prepared By: Paul Seiler
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Deward M. Martin & Associates, Inc.

Submitted By: Original signed by JAMES A. WALSH
JAMES A. WALSH, P.E.
Chief, Design Branch

Recommended By: Original signed by: Carl S. Anderson, Jr.
for JACK G. STARR, P.E.
Chief, Engineering Division

Approved By: Original signed by: LTC Leonard C. Gregor
for DOUGLAS L. HALLER
Colonel, Corps of Engineers
District Engineer

Date SEP 27 1979

Top of Dam

Downstream Face of Dam

SWIFT CREEK RESERVOIR DAM

TABLE OF CONTENTS

SECTION 1

PROJECT INFORMATION

1.1 General:

1.1.1 Authority: Public Law 92-367, 8 August 1972 authorized the Secretary of the Army, through the Corps of Engineers to initiate a national program of safety inspections of dams through the United States. The Norfolk District has been assigned the responsibility of supervising the inspection of dams in the Commonwealth of Virginia.

1.1.2 Purpose of Inspection: The purpose is to conduct a Phase I inspection according to the Recommended Guidelines for Safety Inspection of Dams (Appendix V, Reference 1). The main responsibility is to expeditiously identify those dams which may be a potential hazard to human life or property.

1.2 Project Description:

1.2.1 Dam and Appurtenances: Swift Creek Dam is an earthen embankment dam 1,110 feet long and 37.5 feet high.* The crest of the dam is 25 feet wide at an elevation of 187.5 feet m.s.l. Both the upstream and downstream slopes are 3(H):1(V).

The embankment has an impervious core which is keyed into foundation bedrock and a foundation drainage system. A cross section and plan view of the dam are shown in plates I and II (Appendix I) respectively.

The spillway consists of a 10-inch thick slab, 400 feet wide with a crest elevation of 177.0 feet m.s.l. The downstream slope of the spillway is 4(H):1(V) and water flowing over the spillway is collected in a stilling basin prior to entering the outlet channel.

An 8-foot x 9-foot rectangular water intake tower is located within the reservoir to draw water from the lake. A 30-inch diameter pipe from the tower is used to supply water to the Swift Creek water treatment plant. A second, 60-inch diameter pipe in the tower can be used to lower the reservoir level to elevation 165.0.

1.2.2 Location: Swift Creek Dam is located on Swift Creek, 1/4 mile north of Route 360.

1.2.3 Size Classification: The Swift Creek Dam is classified as an intermediate size structure because of maximum storage capacity (34,800 acre feet.)

*Height is based on the difference in elevation between the crest of the dam and the streambed at the downstream toe of the dam.

1.2.4 Hazard Classification: The dam is located in a suburban area with the possibility of extensive damage and is therefore given a high hazard classification in accordance with guidelines contained in Section 2.1.2 of Reference 1, Appendix V. The hazard classification used to categorize dams is a function of location only and has nothing to do with its stability or probability of failure.

1.2.5 Ownership: The dam is owned by Chesterfield County, Virginia.

1.2.6 Purpose: The reservoir is used to supply water for the Swift Creek Water Treatment Plant. The reservoir is also used for recreational boating and fishing.

1.2.7 Design and Construction History: The dam was designed by J. K. Timmons and Associates, Consulting Engineers, Richmond, Virginia and was constructed in 1965.

1.2.8 Normal Operating Procedures: The dam and water treatment plant are operated by the Department of Utilities for Chesterfield County. There are four 24-inch diameter openings, at various elevations, in the water intake tower which can be opened, as needed, to provide water to the treatment plant. A 30-inch diameter pipe runs from the intake tower to the water treatment plant. An additional 72-inch opening in the water tower can be opened manually by means of a headgate to allow the reservoir to be drained through a 60-inch diameter pipe to a minimum elevation of 165.0.

1.3 Pertinent Data:

1.3.1 Drainage Area: The dam controls a drainage area of 64.32 square miles.

1.3.2 Discharge at Dam Site:

Maximum flood - Unknown.

Spillway
pool level at top of the spillway endwalls . . 29,870 c.f.s.
pool level at the crest of the dam . . . . 44,900 c.f.s.

1.3.3 Dam and Reservoir Data: Pertinent data on the dam and reservoir are shown in the following table:

Table 1.1 DAM AND RESERVOIR DATA

Item	Elevation feet m.s.l.	Reservoir			
		Area acres	Capacity		Length miles
			Acre feet	Watershed inches	
Top of Dam	187.5	2,963	37,230	9.6	5.4
Top of the spillway end-walls	185.0	2,644	30,240	8.1	5.0
Spillway Crest	177.0	1,624	13,180	3.0	3.6
Streambed at the downstream toe of the dam	150±	--	---	--	--

SECTION 2

ENGINEERING DATA

2.1 Design: The dam was designed by J. K. Timmons and Associates, Consulting Engineers, Richmond, Virginia in 1965. The design drawings are included in Appendix I. Also, included in Appendix IV, are copies of the Soil borings, soil inspection and field density tests performed by Froehling and Robertson, Inc. in 1965.

*2.1.2 Geologic Setting of the Dam: The dam site is underlain by the Petersburg Granite Formation. The granite is bound by Triassic-age sandstones and shales approximately 2,000 feet west of the concrete dam, in the general vicinity at Dry Creek. The Virginia State geologic map describes the contact between the granite and the sandstones and shales as a northeast-southwest trending fault contact. The fault contact is not shown to be present beneath the dam.

*2.1.3 Available Geotechnical Data: Soil test borings were performed at the dam site in 1964 by Froehling & Robertson, Inc. of Richmond, Virginia in conjunction with the dam design performed by J. K. Timmons and Associates in 1965. Copies of the boring records are enclosed in Appendix IV.

In 1978, a geotechnical investigation was conducted at the dam site by Schnabel Engineering Associates following the occurence of seepage at the locations of the 60-inch diameter ditch. A copy of their findings is enclosed in Appendix IV. The investigation included a site inspection, a review of existing design data and an engineering analysis of the dam. Three soil test borings were drilled in conjunction with the investigation, two along the crest and one along the downstream toe adjacent to seepage observed around a 60-inch diameter drain. Two observation wells were installed, one at the downstream toe and one just downstream of the core wall along the crest.

Laboratory tests were conducted on undisturbed samples and several jar samples of soil from the embankment. Results of drilling operations and laboratory testing, as well as a detailed description of subsurface conditions are found in Schnabel's report enclosed in Appendix IV.

*2.1.4 Dam Foundation: The dam foundation consists of weathered Petersburg granite (Stratum D in Schnabel's report) with some thin deposits of stream bed deposits (Stratum C) overlying the rock in areas (extent unknown).

*2.1.5 Embankment: The embankment shell consists of firm to coarse silty sand, some clayey silt, silty clayey sand, and sandy silty clay. The fines content ranges from 25 to 52 percent. Natural dry densities ranged from 122 pcf for a sand sample to 104 pcf for a clay sample.

*Information provided by Law Engineering Associates of Virginia.

A consolidated undrained triaxial compression test was performed by Schnabel Engineering Associates on a sample of the dam shell. An angle of internal friction of 14° and a cohesion of 750 psf were determined. Drained parameters were not tested, although a drained friction angle of 27° and a drained cohesion of 0 were used in the stability analyses.

The embankment core consists of firm to medium sandy silty clay and sandy clay, of a stiff to very stiff consistency. A consolidated-undrained triaxial shear test and a direct shear test were performed on a sample of this stratum revealing the following:

	Triaxial Test	Direct Shear Test
Angle of Internal Friction	19°	23°
Cohesion	1500 psf	630 psf

The triaxial compression test data were used in the analyses by Schnabel. Drained parameters of 20° friction and of 0 psf cohesion were estimated by Schnabel.

*2.2 Construction of the Dam: A review of the contract drawings by Schnabel Engineering Associates is enclosed in Appendix IV.

Inspection of fill placement for the dam was provided by Froehling & Robertson, Inc. of Richmond, Virginia. Soil inspection records are enclosed in Appendix IV. The records revealed the fill was tested, in addition, a note recorded on October 5, 1965 stated "It was evident that an undetermined amount of fill was placed Monday." It is not clear as to where the note was referring. However, soil placement on October 5th was in the vicinity of the core and downstream embankment at Stations 3+50 through 5+00 and at an elevation of 175 to 179 m.s.l. The note that uncontrolled fill may have been placed in addition to the fact that some of the embankment soils were placed at four percent above optimum are the only discrepancies from sound construction practice indicated by the inspection records.

Stability analyses were conducted by Schnabel Engineering Associates for the area of the dam adjacent to the 60-inch diameter drain where seepage had been observed. The analyses considered the effects of sudden drawdown of the reservoir on the upstream slope and steady state seepage on the downstream slope. It is understood that the line of seepage for steady state conditions was developed from observation well readings as shown in Drawing 3 of Schnabel's report in Appendix IV. The results of the analyses are as follows:

Case	Loading Condition	Factor of Safety	Required Minimum Factor of Safety
I	Sudden Drawdown of Reservoir (upstream slope)	3	1.2
III	Steady Seepage (downstream slope)	1.5	1.5

It should be noted in Drawing 3 that the critical failure circle for Case I loading conditions goes through Stratum D. There was no laboratory data presented for Stratum D and it is highly unlikely a critical failure would occur in this very dense material weathered rock rather than in the Stratum B soils (clay blanket) above it.

In addition, the line of seepage estimated from observation well readings taken on June 26, 1979, is significantly higher than that used in Schnabel's analysis.

*2.3 Evaluation: The assumed parameters appear to be sufficient to evaluate the structural stability of the dam. The phreatic surface elevation, indicated by B-2 at the time of the inspection, was about 15 feet higher than the phreatic level used by Schnabel Engineering Associates in their stability analyses of the downstream slope. This discrepancy would result in a much lower factor of safety than the F.S. value of 1.46 indicated in Schnabel's report.

*Information provided by Law Engineering Associates of Virginia.

SECTION 3

VISUAL INSPECTION

3.1 Findings:

3.1.1 General: The results of the 25 June 1979 inspection are recorded in Appendix III. At the time of the inspection, the pool elevation was 177.0 feet m.s.l. which is normal. A previous inspection of the dam, performed in 1978 by J. K. Timmons and Associates, Inc., Richmond, Virginia, is included in Appendix IV. The ground around the abutments was dry and covered with grass and small shrubs. There were no obvious signs of sloughing or erosion.

During the present site inspection, water level readings were taken in two observation wells, B-2 located at the crest of the dam and just downstream of the core, and B-3 located just downstream of B-2, at the toe of the dam. The water level readings taken on June 25, 1979 (Plate 1, Appendix III) indicated either the core wall is not functioning or the pool elevation is above the core and water is following a line of seepage above it.

Water level readings taken in 1978 indicated the core was functioning properly. Plate 1 in Appendix III is a typical cross-section of the dam taken at the observation well locations, and shows the two approximate lines of seepage.

3.1.2 Dam: The embankment appears to be in good condition, however, some surface erosion was noted on the downstream slope at the toe of the embankment, approximately 400 feet to the right of the left abutment (see Photograph of downstream face of the dam, Page iii.)

3.1.3 Appurtenant Structures: Observations of the intake tower indicated that it was in good condition. The four 24-inch headgates, used for supplying water to the treatment plant, and the 72-inch headgate, used to allow water to pass through the 60-inch diameter pipe, all appeared to be in good condition.

*Evidence of seepage, approximately 1 gpm, was observed adjacent to a 60-inch diameter drain located at the downstream toe of the dam. Marsh grass, cattails and saturated soils were observed adjacent to the pipe.

*Adjacent to the retaining wall on the left side of the spillway, embankment soils were saturated over an area starting about 12 feet to the left of the wall and extending downstream a distance of about 10 feet.

*Information provided by Law Engineering Associates of Virginia.

3.1.4 Spillway: The general condition of the concrete spillway surface was good although some small cracks were noted. The inspection also revealed some seepage in the concrete slab joints.

3.1.5 Reservoir Area: The surrounding area is wooded and flat with no shoreline erosion or apparent slope failures. There is no information available pertaining to sedimentation.

3.1.6 Downstream Channel: Water flowing over the spillway crest is initially collected in a stilling basin. The stilling basin is approximately 400 feet long and 170 feet wide with side slopes of 4(H): 1(V). The outlet channel extends 620 feet from the stilling basin to the natural streambed.

The natural streambed is about 50 feet wide with side slopes of about 6(H):1(V). The natural streambed is covered with small shrubs, grass and trees.

3.2 Evaluation: The dam, in general, appears to be in good condition. It is recommended, however, that remedial action be taken to repair the sealer in the slab joints on the spillway. The areas of the embankment where erosion has occured should be repaired and reseeded. The causes of the high phreatic surface as indicated by the reading of the observation wells should be investigated.

SECTION 4

OPERATIONAL PROCEDURES

4.1 Procedure: The normal pool elevation is 177.0 feet, which is the crest of the spillway. The primary function of the reservoir is to provide water for the Swift Creek water treatment plant. The water is discharged into the treatment plant through a 30-inch diameter concrete pipe, at elevation 167.0, which runs from the water intake tower in the reservoir to the treatment plant. The water in the tower is regulated manually by opening up to four 24-inch diameter inlets, two at elevation 167.0, one at elevation 169.0 and one at elevation 172.0 A separate 72-inch headgate is used to regulate water passing through the 60-inch diameter drain pipe with the capability of lowering the reservoir to elevation 165.0.

4.2 Maintenance: The Chesterfield County Department of Utilities maintains the dam in conjunction with the water treatment plant. Routine maintenance consists primarily of mowing and insuring that the inlet and outlet structures are free of debris.

4.3 Warning System: At the present time there is no warning system or evacuation plan in operation.

4.4 Evaluation: The normal operation and maintenance of this dam is performed by the Chesterfield County Department of Utilities together with the operation and maintenance of the Swift Creek Water Treatment Plant. The dam does not require extensive operational procedures and the current system seems to be functional. The program for routine maintenance seems to be adequate, however, unusual problems such as the failure of the joint material should be examined and corrected through an annual inspection program.

SECTION 5

HYDRAULIC/HYDROLOGIC DATA

5.1 Design: No data were available.

5.2 Hydrologic Records: None were available.

5.3 Flood Experience: No records were available.

5.4 Flood Potential: The PMF and 1/2 PMF were developed and routed through the reservoir by use of the HEC-1 computer program (Reference 2, Appendix V) and appropriate unit hydrograph, precipitation, and storage-outflow data. Clark's Tc and R coefficients for the local drainage area were estimated from basin characteristics. The rainfall applied to the developed unit hydrograph was obtained from a U S Weather Bureau Publication (Reference 3, Appendix V). Losses were estimated at an initial loss of 1.0 inch and a constant loss thereafter of 0.05 inch/hour.

5.5 Reservoir Regulation: Pertinent dam and reservoir data are shown in Table 1.1.

Water is passed from Swift Creek Reservoir to the water treatment plant located approximately 600 feet from the dam. A 30-inch pipeline from a water intake tower in the reservoir runs through the dam to the treatment plant. Water also flows past the dam over the spillway in the event water in the reservoir rises above elevation 177.0.

The storage curve was calculated by use of U S Geological Survey Quadrangle Maps. Rating curves were developed for the spillway and non-overflow section of the dam. In routing hydrographs through the reservoir, it was assumed that the initial pool level was at the spillway crest. Flow to the water treatment plant was neglected during routing.

5.6 Overtopping Potential: The probable rise of the reservoir and other pertinent information on reservoir performance is shown in the following table:

10

Table 5.1 RESERVOIR PERFORMANCE

Item	Normal Flow	Hydrograph 1/2 PMF	Hydrograph PMF (a)
Peak Flow, c.f.s.			
Inflow	64	57,615	115,231
Outflow	--	35,422	85,180
Maximum Elevation feet, m.s.l.		186.0	190.7
Spillway (Elevation 177.0)			
Depth of flow, feet		9.0	13.7
Velocity, fps (b)		14.2	17.5
Non-overflow section (Elevation 187.5)			
Depth of flow, feet		--	3.2
Duration, hours		--	10
Velocity, fps (b)		--	1.9
Tailwater elevation, feet m.s.l.	149±		

(a) The PMF is an estimate of flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

(b) Critical velocity.

5.7 Reservoir Emptying Potential: a 72-inch headgate along with a 60-inch diameter drain pipe at elevation 161.0 are available for dewatering the reservoir. The gate will permit withdrawal of about 328 c.f.s. with the reservoir level at the crest of the spillway and essentially dewater the reservoir to elevation 165.0 in about 31 days, assuming a normal inflow of 64 c.f.s.

5.8 Evaluation: Based on the size (intermediate) and hazard (high) classifications, the recommended Spillway Design Flood is the PMF. The spillway will pass 43% of the PMF without overtopping the spillway endwalls, and 60% without overtopping the dam. The PMF will overtop the spillway endwalls for 14 hours and reach a maximum of 5.7 feet over the top of the spillway endwalls. The PMF will also overtop the dam for 10 hours and reach a maximum of 3.2 feet over the top of the dam, with an average critical velocity of 1.9 feet per second.

Conclusions pertain to present day conditions. The effect of future development on the hydrology has not been considered.

SECTION 6

STRUCTURAL STABILITY

*6.1 Foundation and Abutments: The dam is constructed on the weathered Petersburg Granite with isolated alluvial deposits above the granite at several locations (extent unknown). The alluvial deposits were to have been removed during construction, and from the borings performed by Schnabel Engineering Associates, it appears that the majority of these deposits were removed.

6.2 Embankment:

*6.2.1 Materials: The contract drawings called for the embankment shell to be constructed of soil excavated during the construction of the spillway and that soils were to be compacted to 95% of maximum dry density. The embankment core was to be constructed of clay imported to the site. In accordance with the 1978 report by Schnabel Engineering and Associates (Appendix IV), the installation of this fill was adequately inspected to insure compliance with design specifications.

*6.2.2 Stability: Stability calculations were performed by Schnabel Engineering Associates in 1978, using a combination of tested and assumed soil parameters. The results of the stability analyses are reported in Section 2 (Refer to Appendix IV).

* 6.3 Evaluation: Visual observations do not reveal any problems which indicate instability, except for water seepage adjacent to a 60-inch diameter drain located at the downstream toe of the slope. The assumed strength parameters appear sufficient to evaluate the structural stability of the dam. However, the phreatic surface elevation, indicated by B-2 at the time of inspection, is about 15 feet higher than the phreatic level used by Schnabel Engineering Associates in their stability analyses of the downstream slope. This discrepancy would result in a much lower factor of safety than the F. S. value of 1.46 indicated in Schnabel's report.

*Information Provided by Law Engineering Associates of Virginia.

SECTION 7

ASSESSMENT AND REMEDIAL MEASURES/RECOMMENDATIONS

7.1 Dam Assessment:

7.1.1 Based on criteria established by the Department of the Army, Office of the Chief of Engineers (OCE), the Spillway Design Flood is the PMF. The spillway will pass 60% of the PMF without overtopping the dam. The SDF will overtop the dam by 3.2 feet with an average critical velocity of 1.9 feet per second. The spillway is therefore adjudged inadequate.

Seepage was observed adjacent to the 60-inch diameter outlet pipe and in the joints on the concrete spillway. The sealer in these joints has deteriorated to a large degree allowing moisture to seep through in several locations. Erosion was also detected in two areas on the downstream side of the embenkment. These need remecial action.

*7.1.2 From a geotechnical standpoint, the dam appears to be functioning well, with the exception of seepage conditions as noted in Section 3. In addition, the water level readings obtained on June 26, 1979 at two observation wells at the crest and downstream toe indicate either the core is not functioning properly or the pool had risen and seepage was occurring above the core. The higher line of seepage created by this condition makes the stability of the dam questionable.

The available geotechnical engineering data and assumptions made for the strength properties of the embankments and foundations are generally acceptable. The possibility of a higher phreatic surface as observed at the time of inspection was not considered in previous stability analyses. Assuming that the core was constructed properly, it is not unreasonable to expect the phreatic surface level in the embankment to fluctuate due to changes in precipitation and pool level. Therefore, the factor of safety for the downstream slope which was determined by using a phreatic surface much lower than observed on June 26, 1979 is not considered acceptible.

*7.2 Recommended and Remedial Measures: Action should be taken to determine whether the core is functioning and to determine the present stability of the dam. The evidence of seepage adjacent to the 60-inch diameter drain and around the left side of the spillway should be investigated so that remedial measures can be implemented. The sealer in the joints on the concrete spillway should be repaired as soon as possible and the areas of the embankment where erosion has occured should be repaired and reseeded.

*Information provided by Law Engineering Associates of Virginia.

*7.2.1 It is recommended that the owner, at his own expense, secure the services of a professional engineer to monitor the seepage and phreatic levels to determine whether any further studies are necessary. The engineer should also make recommendations to corrective measures suggested in 7.2.

The owner should have a schedule for these investigations within 2 months after the date of notification by the Governor of the Commonwealth of Virginia.

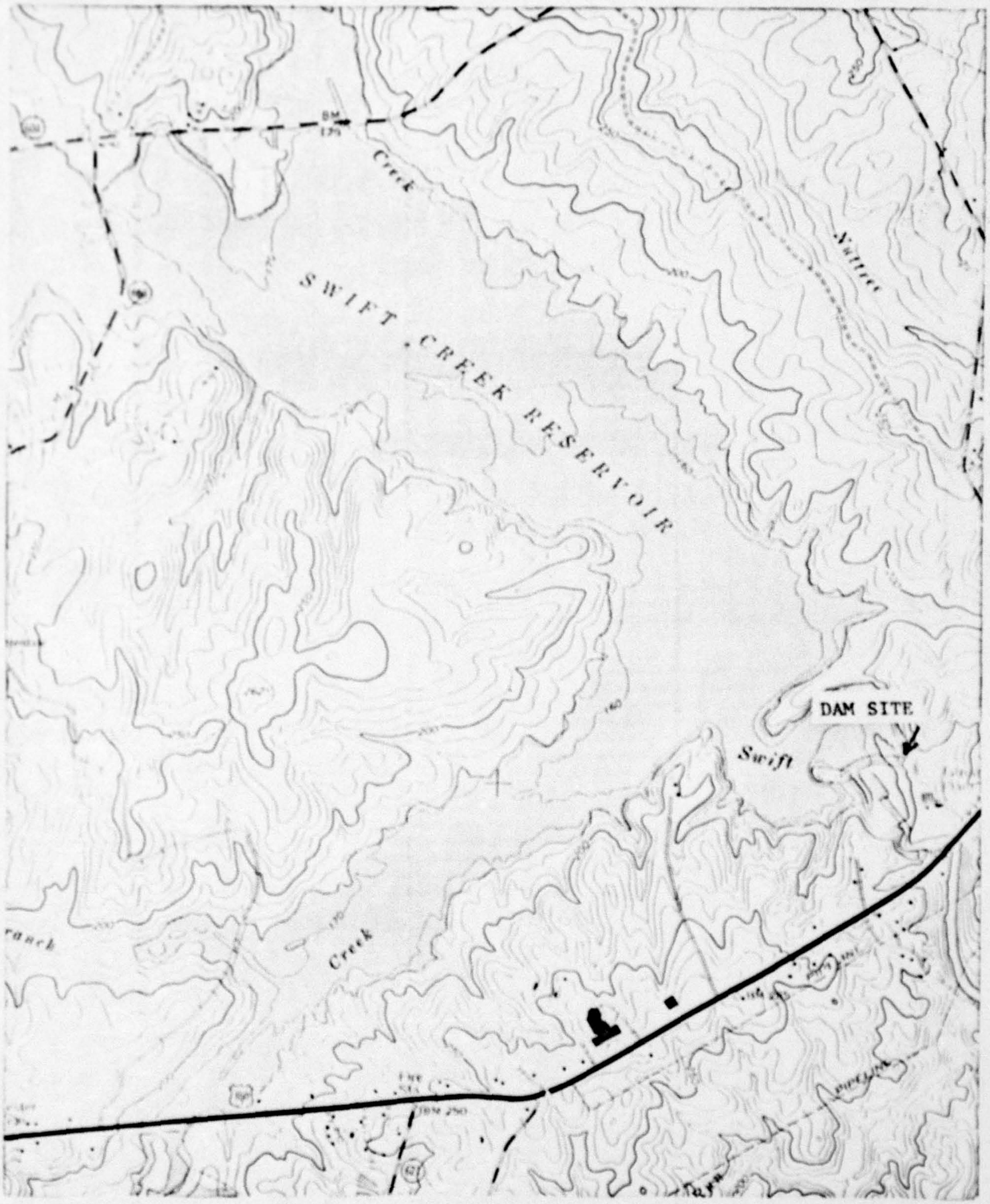
The schedule for completion of remedial work which may result from the investigation should be in agreement with the Commonwealth of Virginia for a reasonable time frame when all measures will be completed.

*Information provided by Law Engineering Associates of Virginia.

APPENDIX I

MAPS AND DRAWINGS

REGIONAL MAP
SWIFT CREEK RESERVOIR

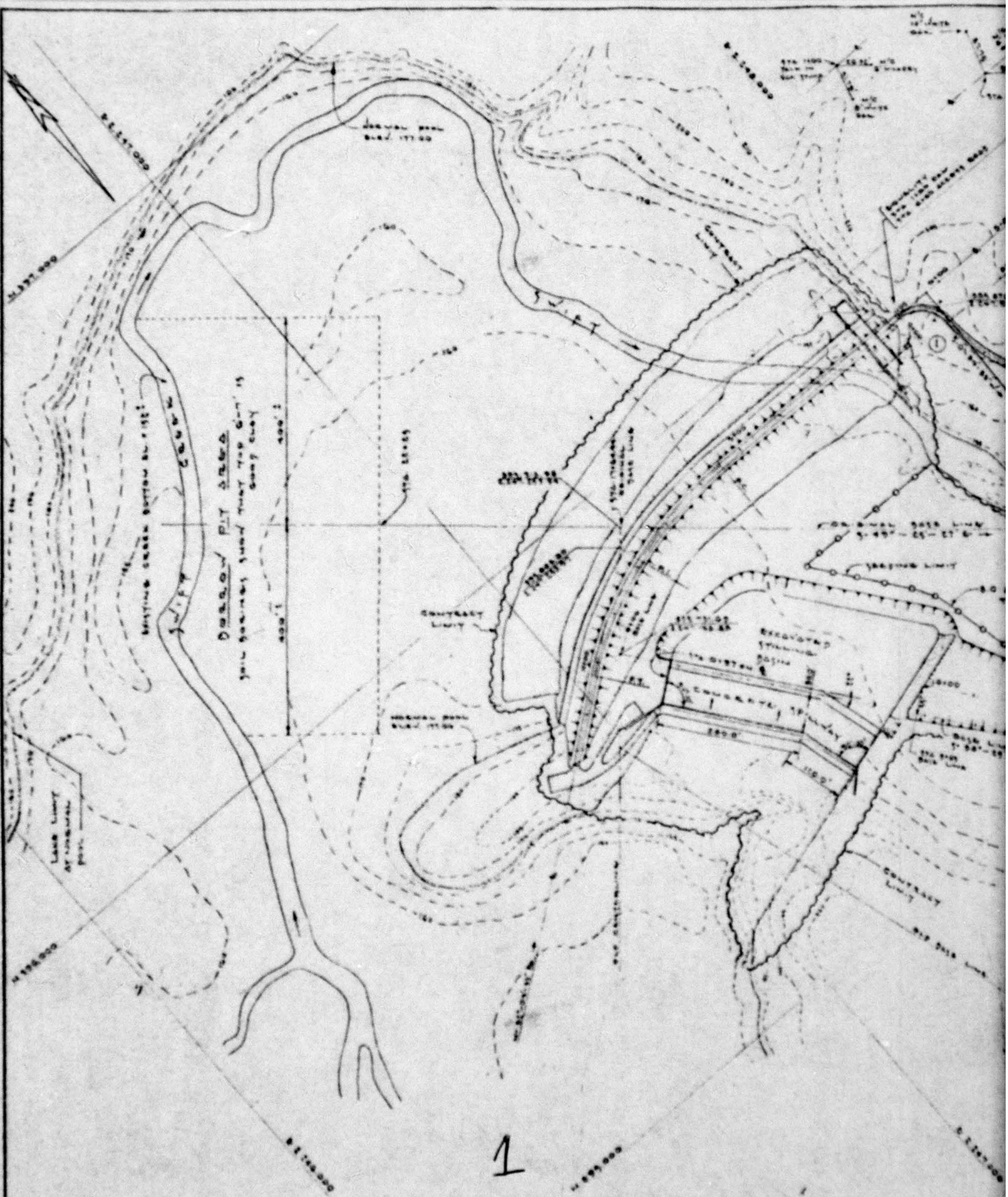


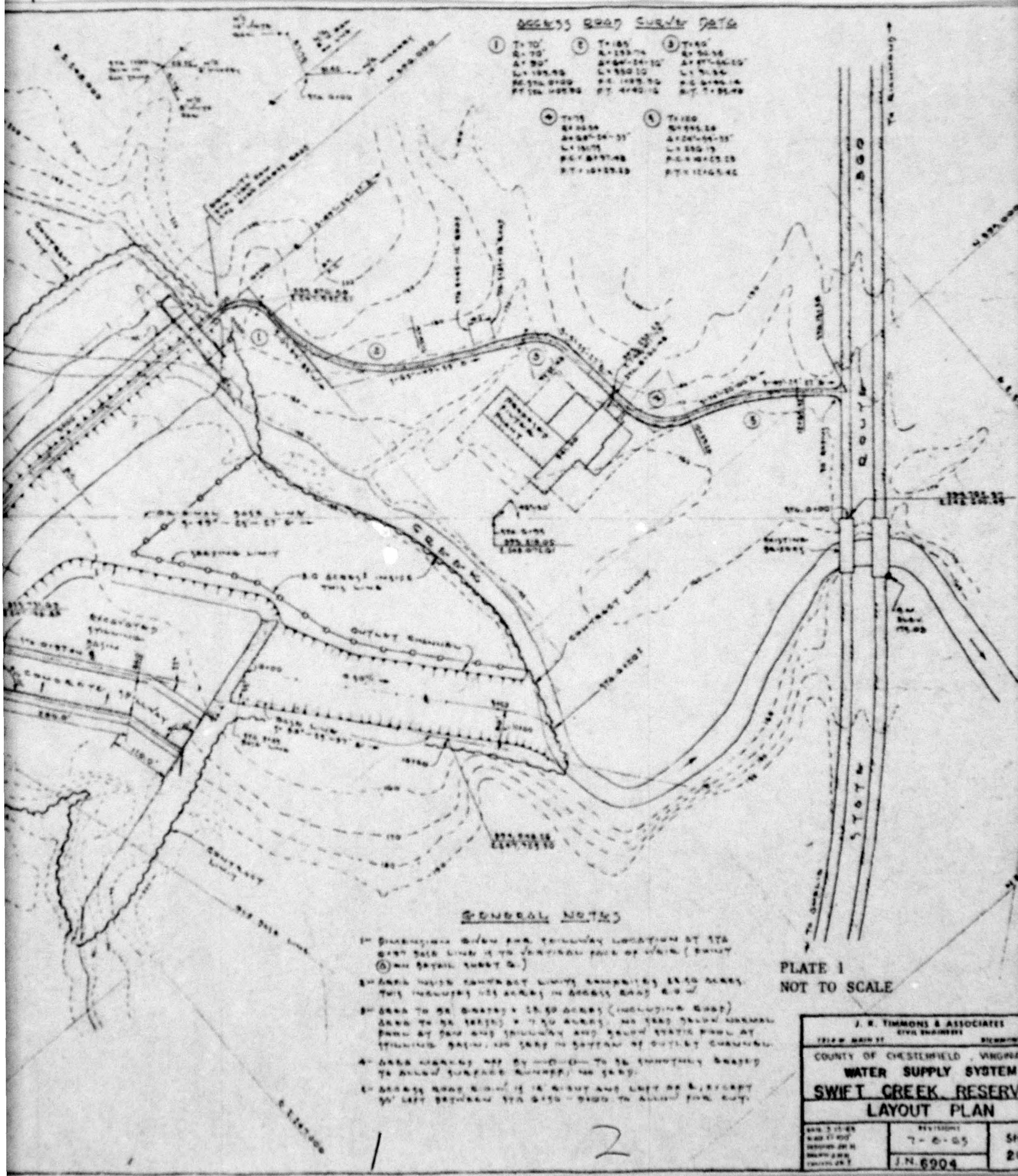
HALLSBORO, VA.
N3722.5—W7737.5/7.5
1963
PHOTOREVISED 1968 AND 1974
AMS 5458 I NW—SERIES V834

UTM GRID AND 1974 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

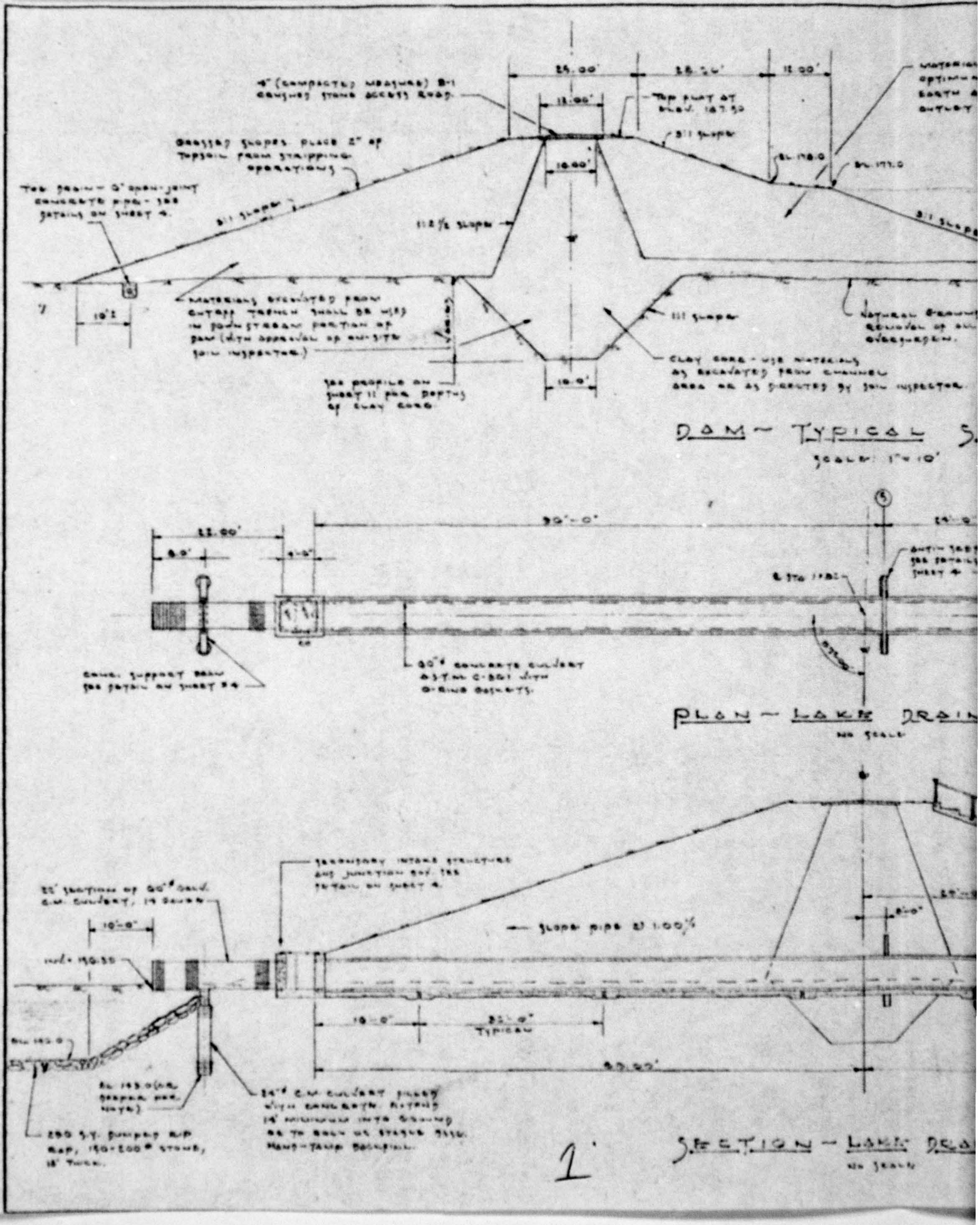
SCALE: 1" = 2000'
10' Contours

VICINITY MAP
SWIFT CREEK RESERVOIR

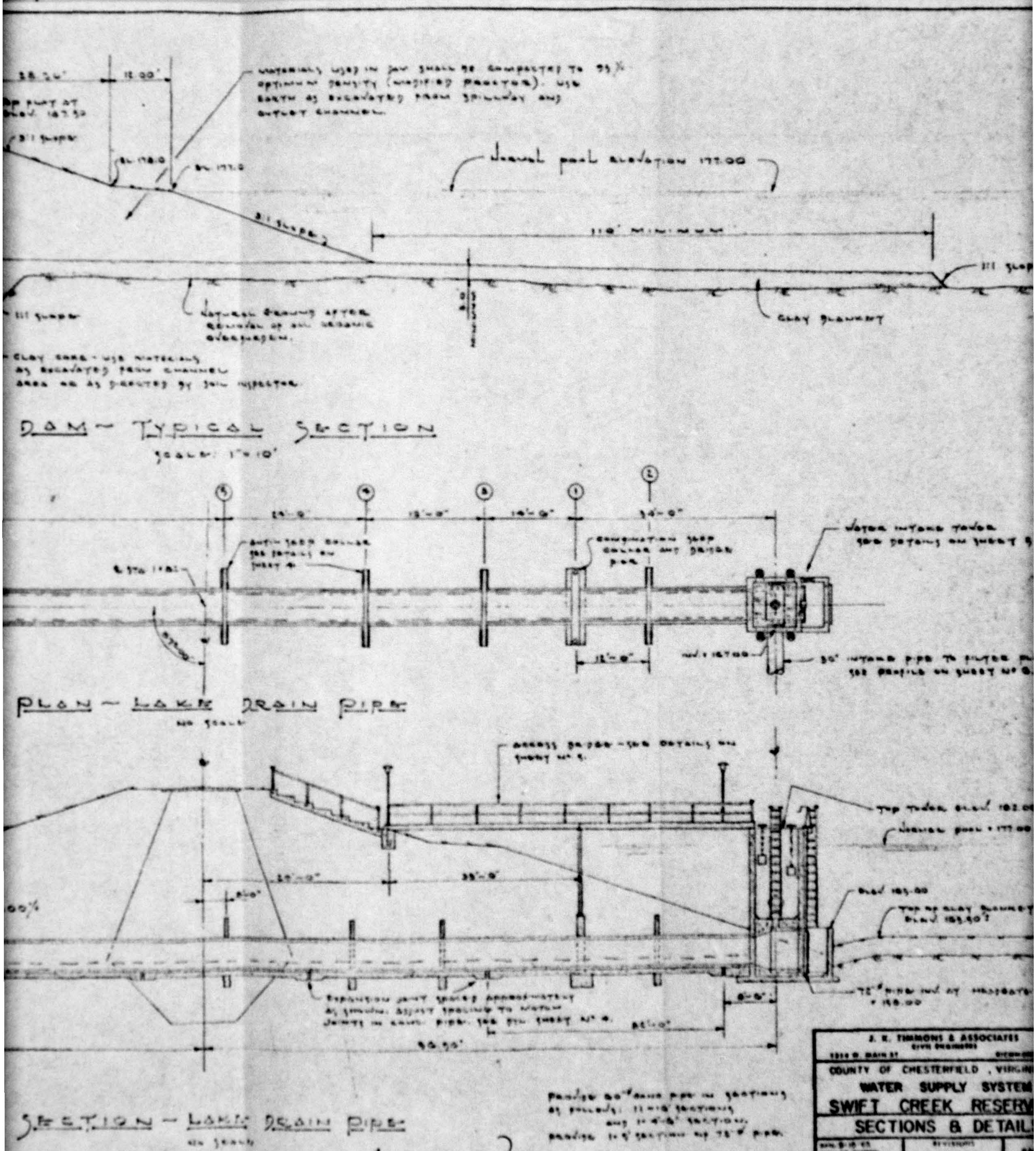

BORROW PIT AREA
CONTRACT LIMIT
1



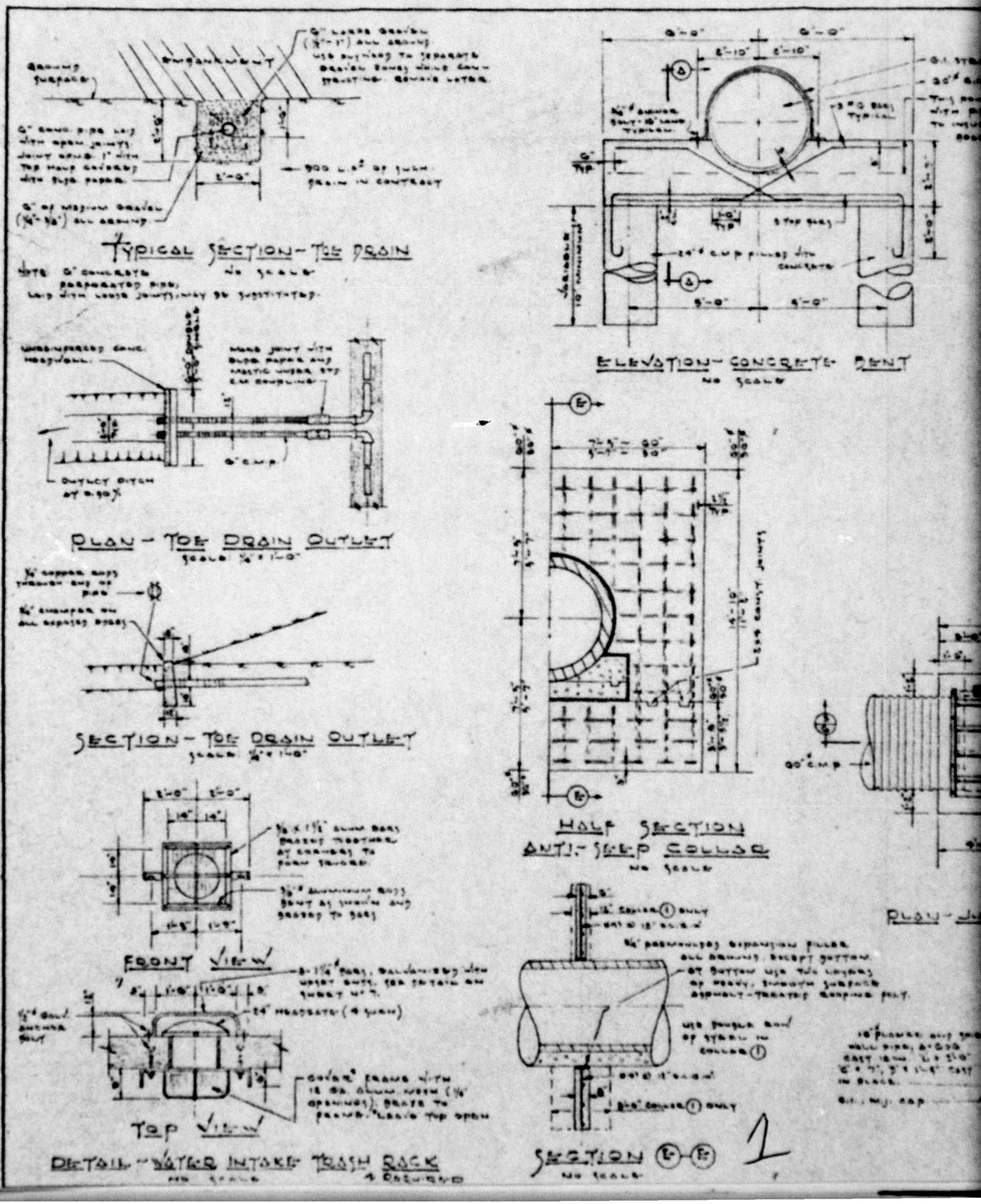
GENERAL NOTES
PLATE 1
NOT TO SCALE
J. K. TIMMONS & ASSOCIATES
COUNTY OF CHESTERFIELD , VIRGINIA
WATER SUPPLY SYSTEM
SWIFT CREEK RESERVO
LAYOUT PLAN
7-6-65
J.N. 6904
1
2



25.00'
12.00'
10.00'
3:1 slope
1:1 slope
DAM — TYPICAL S
SCALE: 1"=10'
22.00'
30'-0"
30" concrete culvert ASTM C-361 with O-ring gaskets
PLAN — LAKE DRAIN
NO SCALE
Slope pipe @ 1.00%
10'-0"
32'-0" TYPICAL
SECTION — LAKE DRAI
NO SCALE
1



1 2 PLATE 2 NOT TO SCALE


GROUND SURFACE
EMBANKMENT
TYPICAL SECTION - TOE DRAIN
NO SCALE
PLAN - TOE DRAIN OUTLET
SECTION - TOE DRAIN OUTLET
FRONT VIEW
TOP VIEW
DETAIL - WATER INTAKE TRASH RACK
NO SCALE
ELEVATION - CONCRETE BENT
NO SCALE
HALF SECTION
ANTI-SEEP COLLAR
NO SCALE
SECTION E-E
NO SCALE
1

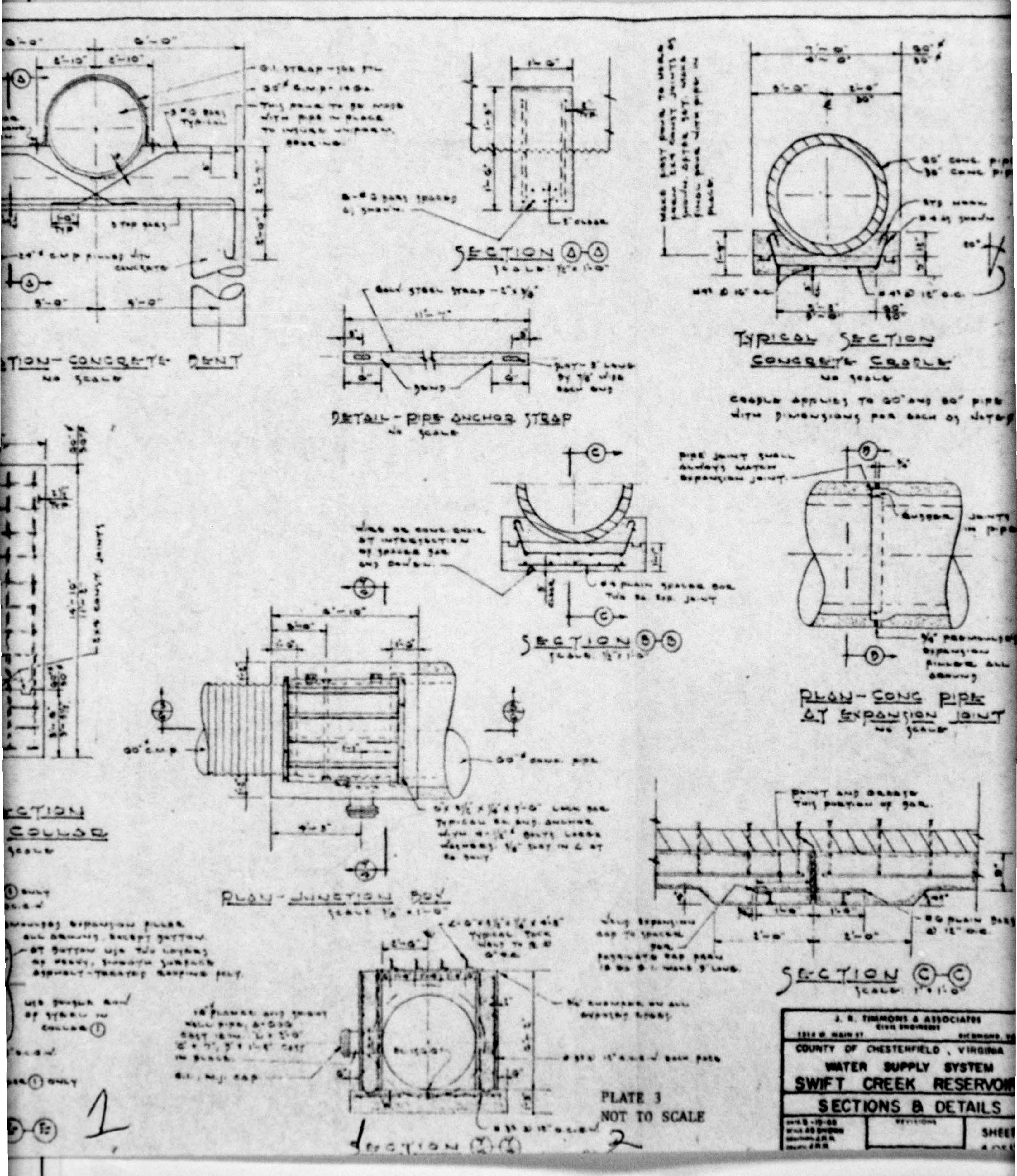
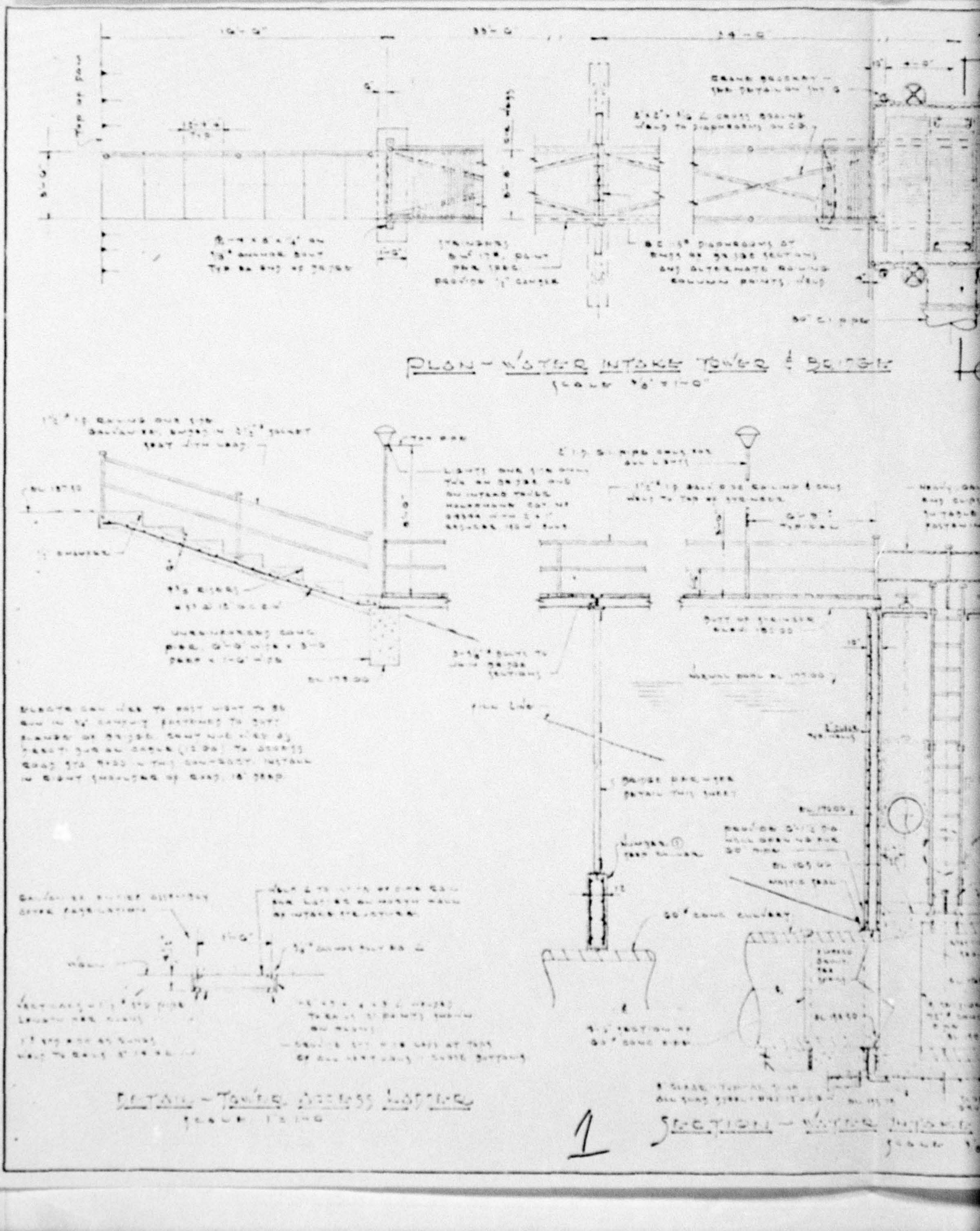


PLATE 3
NOT TO SCALE



PLAN – WATER INTAKE TOWER & BRIDGE
DETAIL – TOWER ACCESS LADDER
SECTION – WATER INTAKE
1

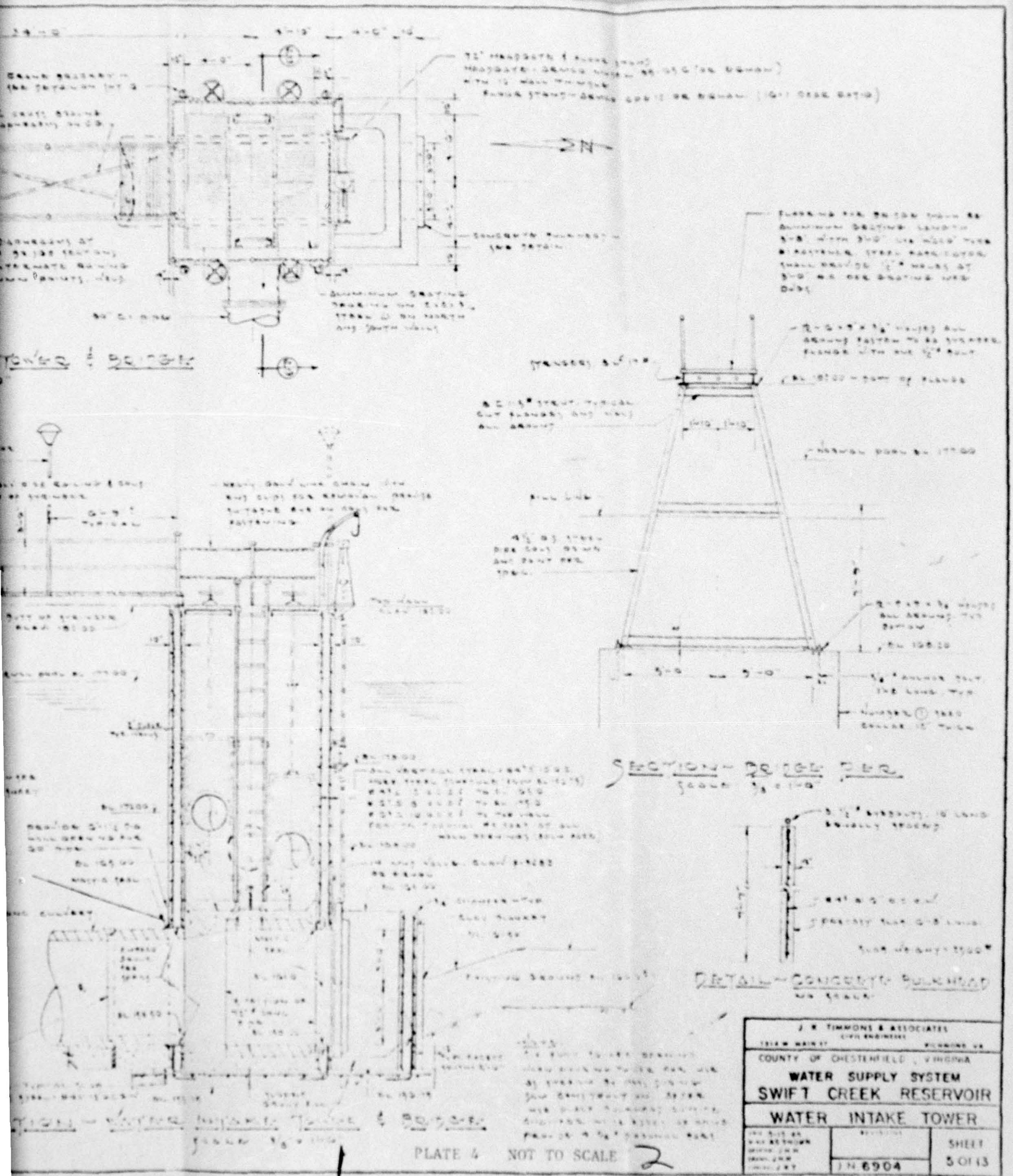
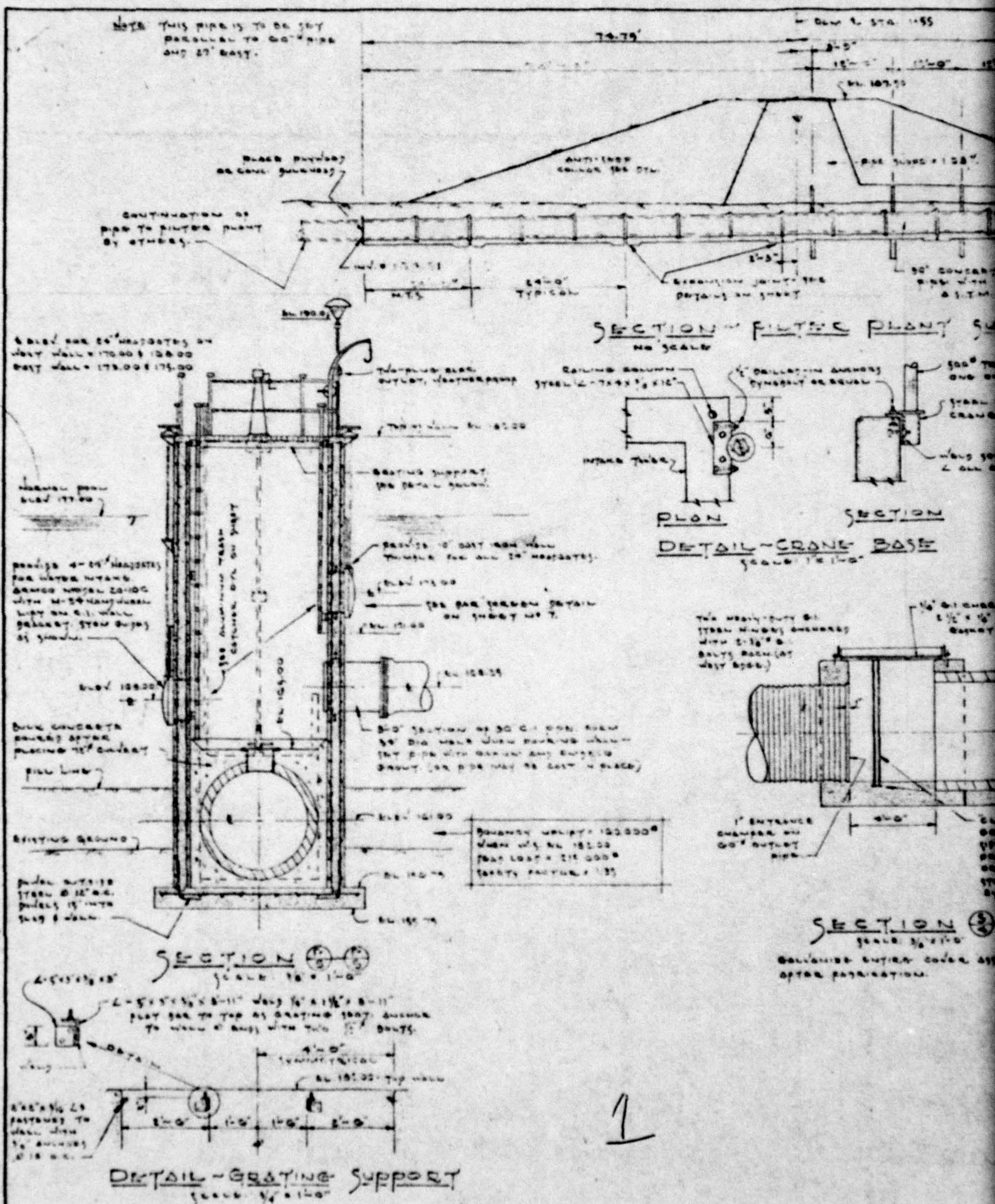


PLATE 4 NOT TO SCALE


SECTION - FILTER PLANT
NO SCALE
PLAN
SECTION
DETAIL - CRANE BASE
SECTION
SECTION
DETAIL - GRATING SUPPORT
1

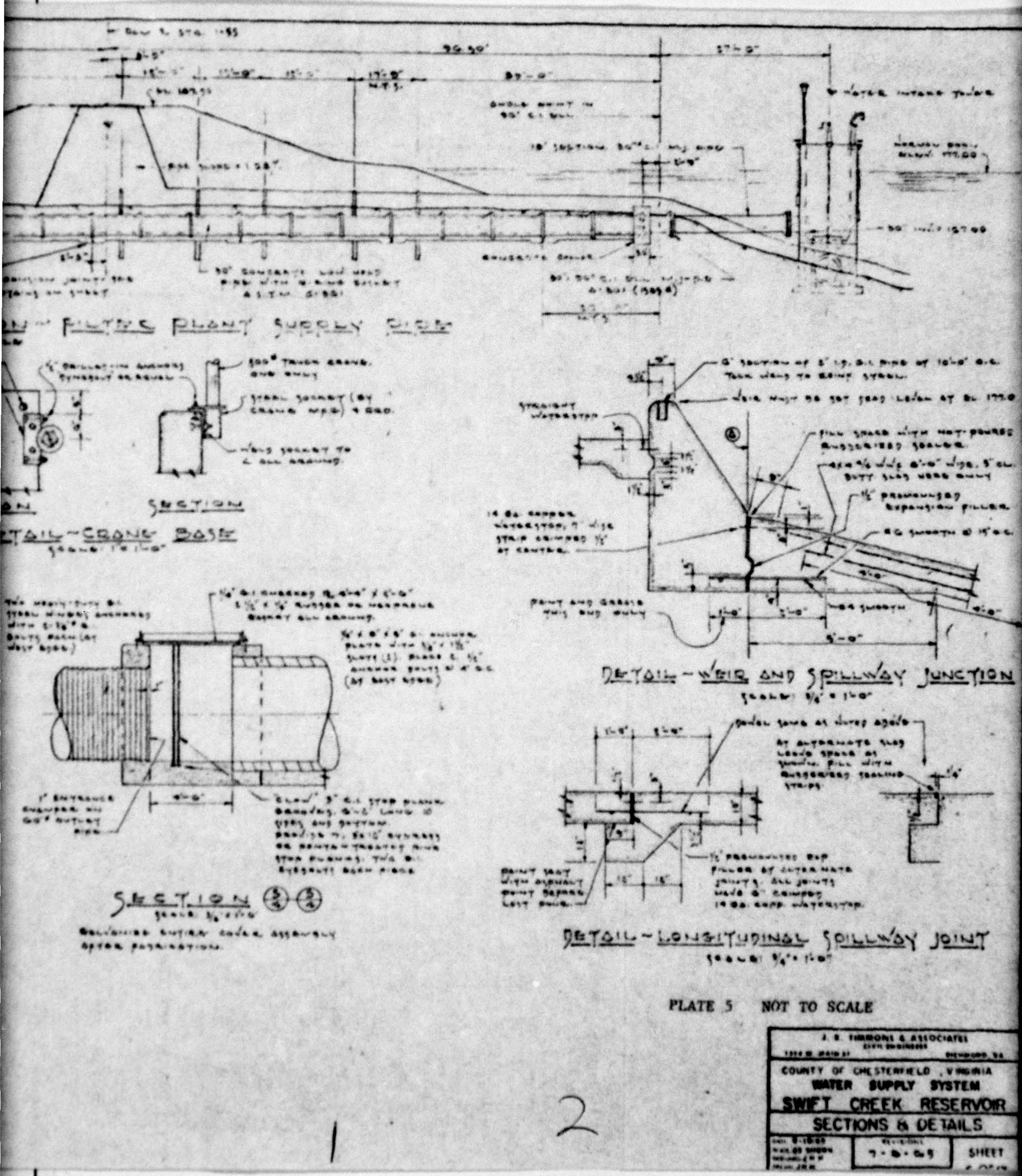
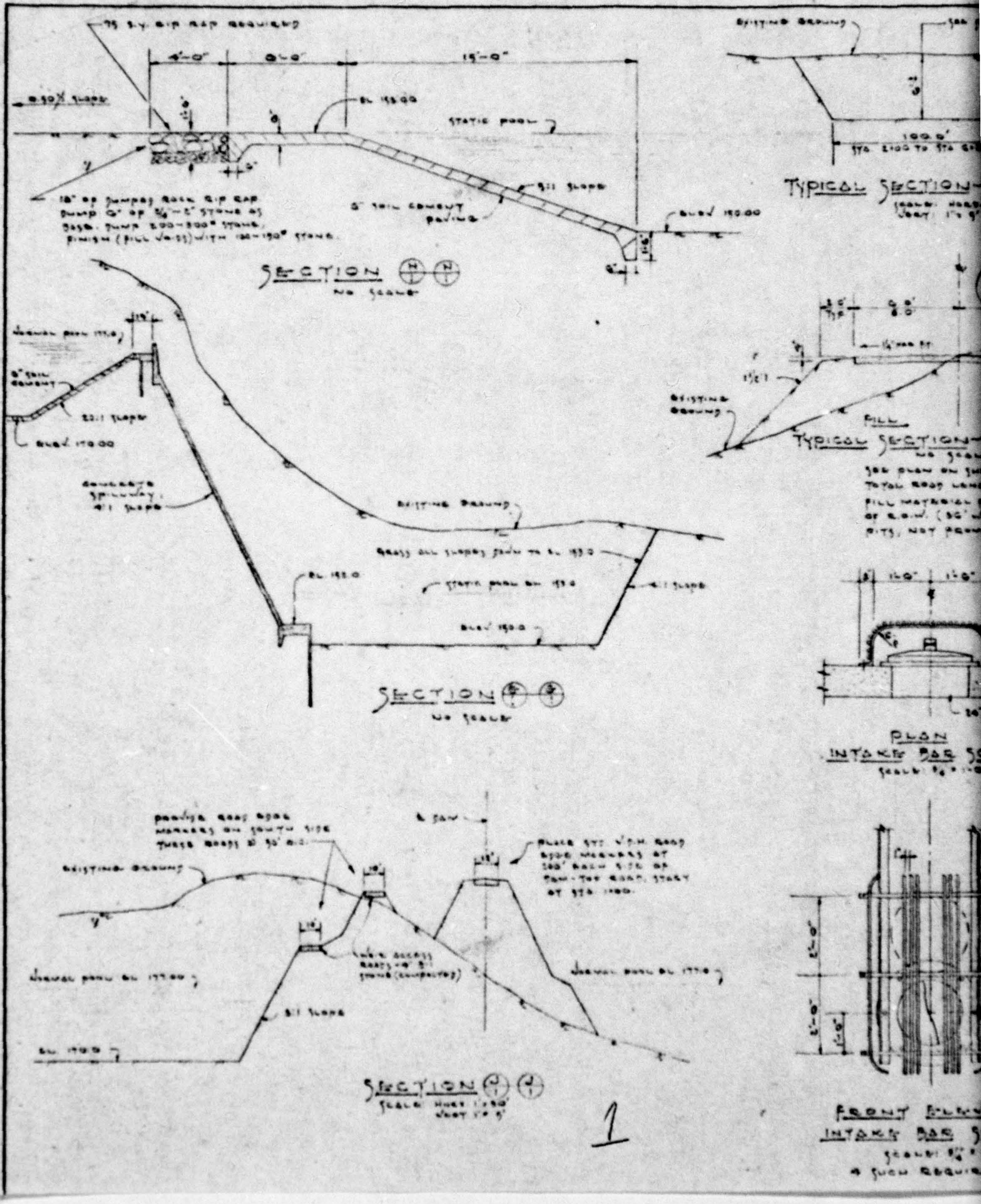


PLATE 5 NOT TO SCALE



4'-0"
15'-0"
STATIC POOL
3:1 SLOPE
SECTION
NO SCALE
EXISTING GROUND
SECTION
NO SCALE
EXISTING GROUND
SECTION
TYPICAL SECTION
TYPICAL SECTION
PLAN
1

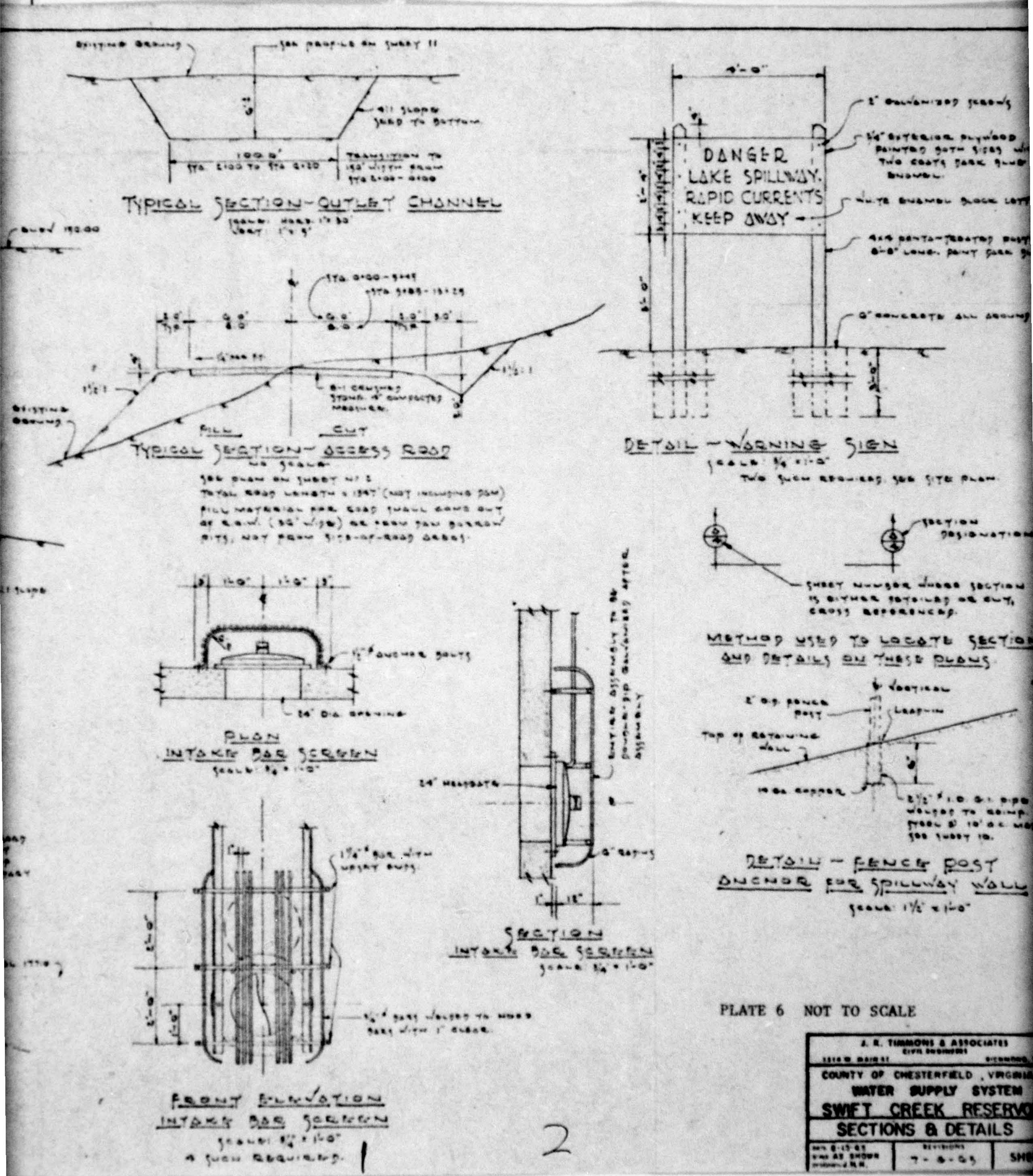
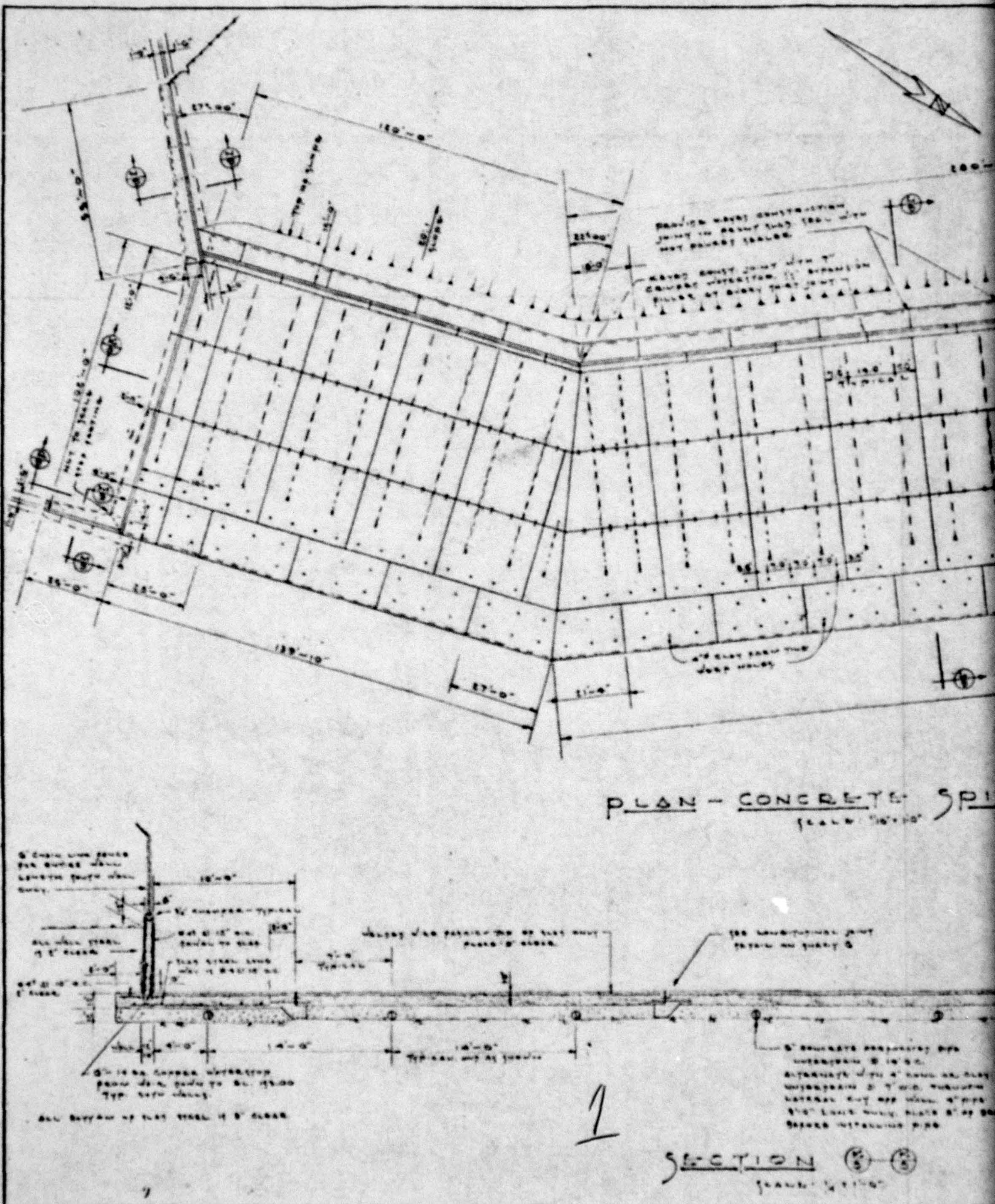
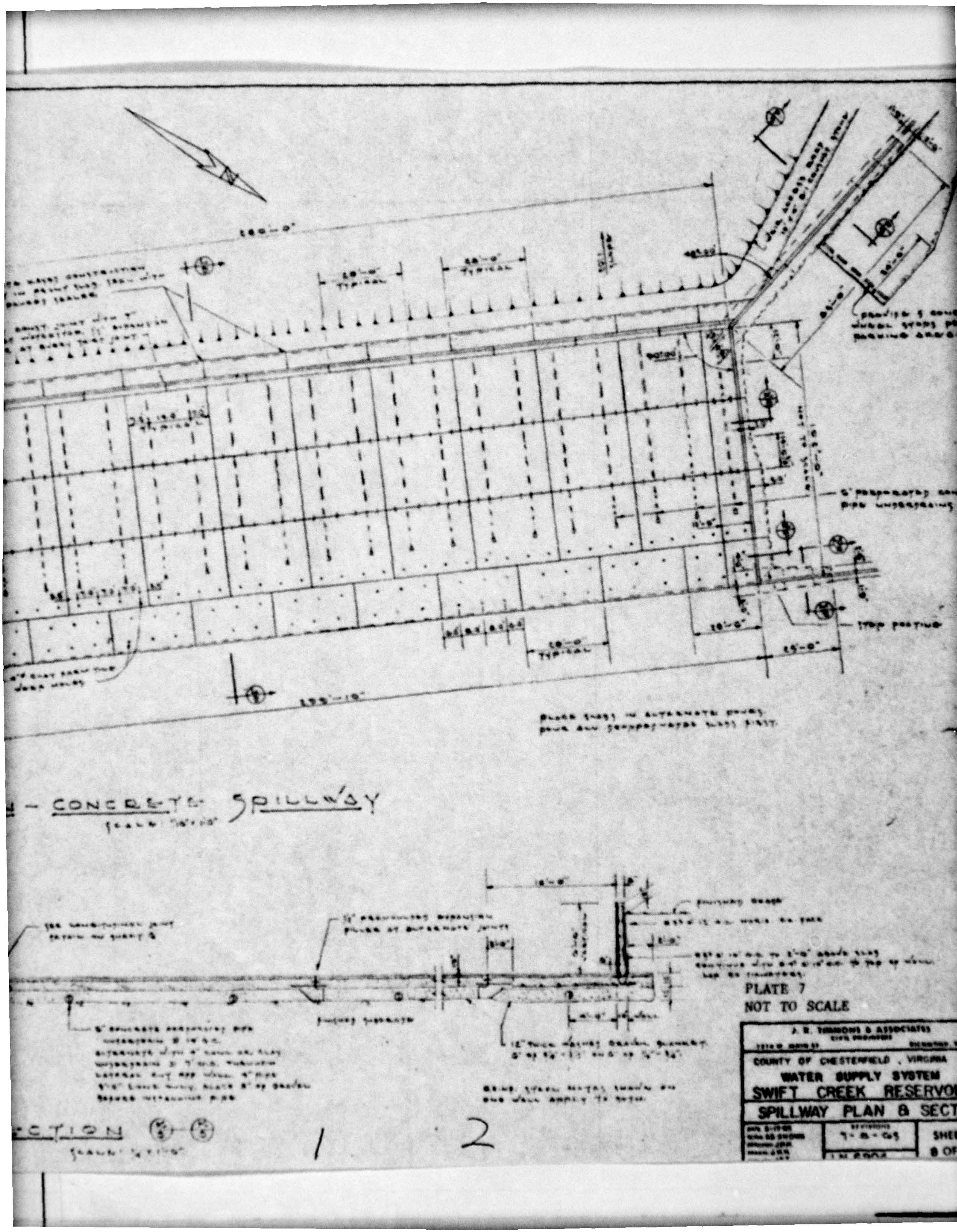
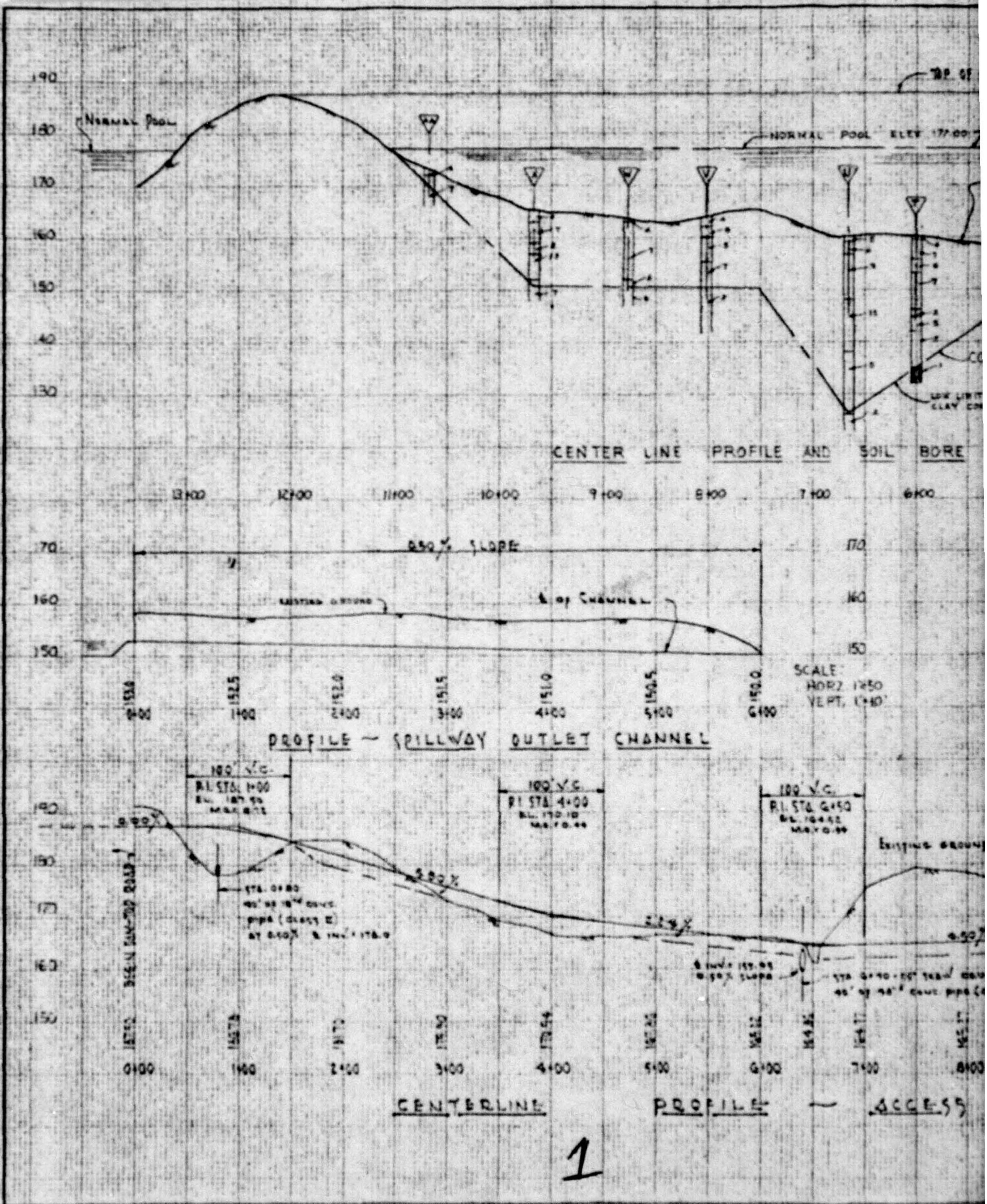


PLATE 6 NOT TO SCALE


PLAN - CONCRETE SP
1
SECTION



CONCRETE SPILLWAY
CTION
1
2
PLATE 7
NOT TO SCALE
COUNTY OF CHESTERFIELD, VIRGINIA
WATER SUPPLY SYSTEM
SWIFT CREEK RESERVOI
SPILLWAY PLAN & SECT.



NORMAL POOL
NORMAL POOL ELEV 177.00
CENTER LINE PROFILE AND SOIL BORE
13+00
12+00
11+00
10+00
9+00
8+00
7+00
6+00
0.50% SLOPE
EXISTING GROUND
℄ of CHANNEL
SCALE:
HORZ. 1"=50'
VERT. 1"=10'
0+00
1+00
2+00
3+00
4+00
5+00
6+00
PROFILE ~ SPILLWAY OUTLET CHANNEL
100' V.C.
P.I. STA. 1+00
100' V.C.
P.I. STA. 4+00
100' V.C.
P.I. STA. 6+50
EXISTING GROUND
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
CENTERLINE PROFILE ~ ACCESS
1

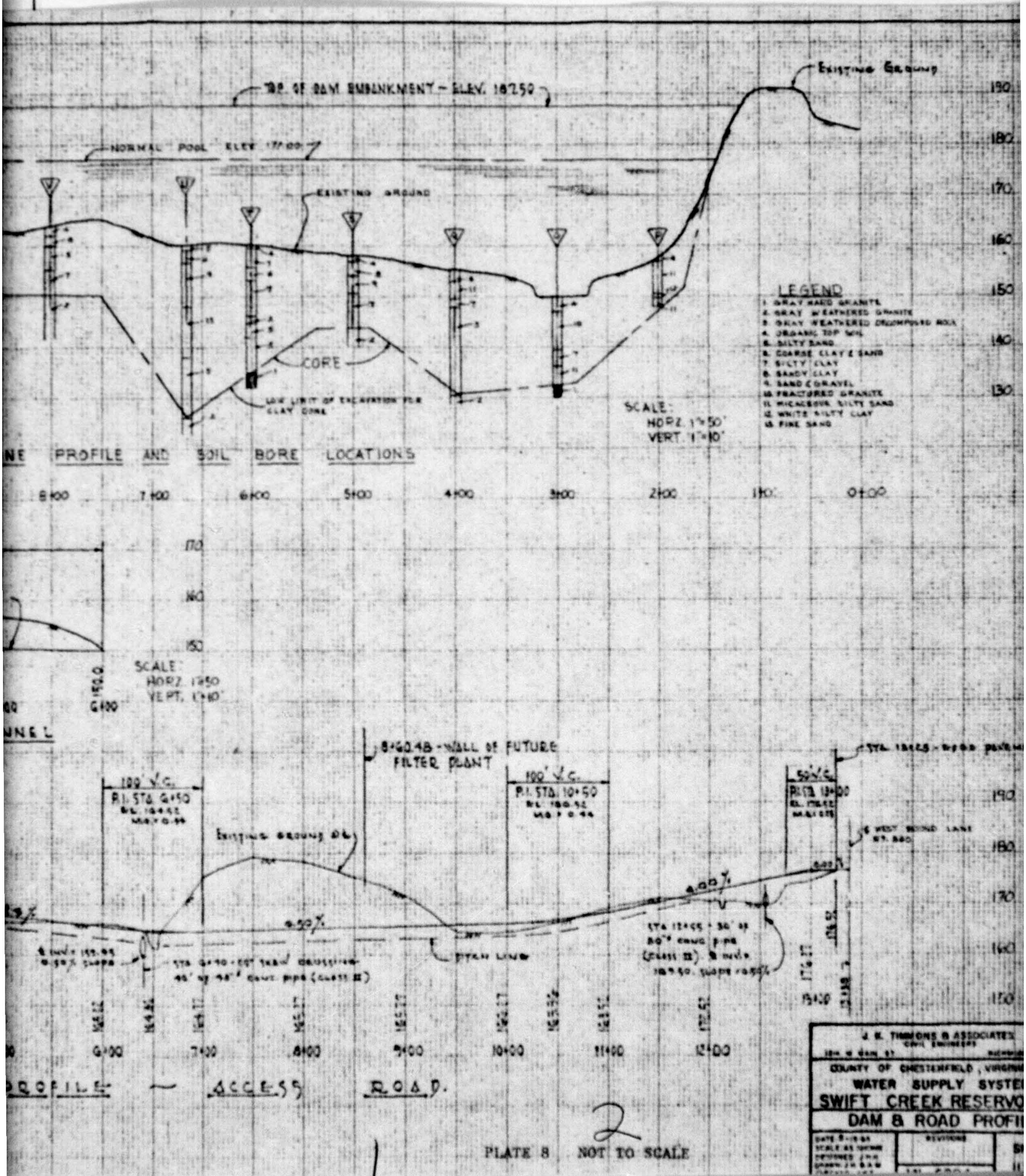


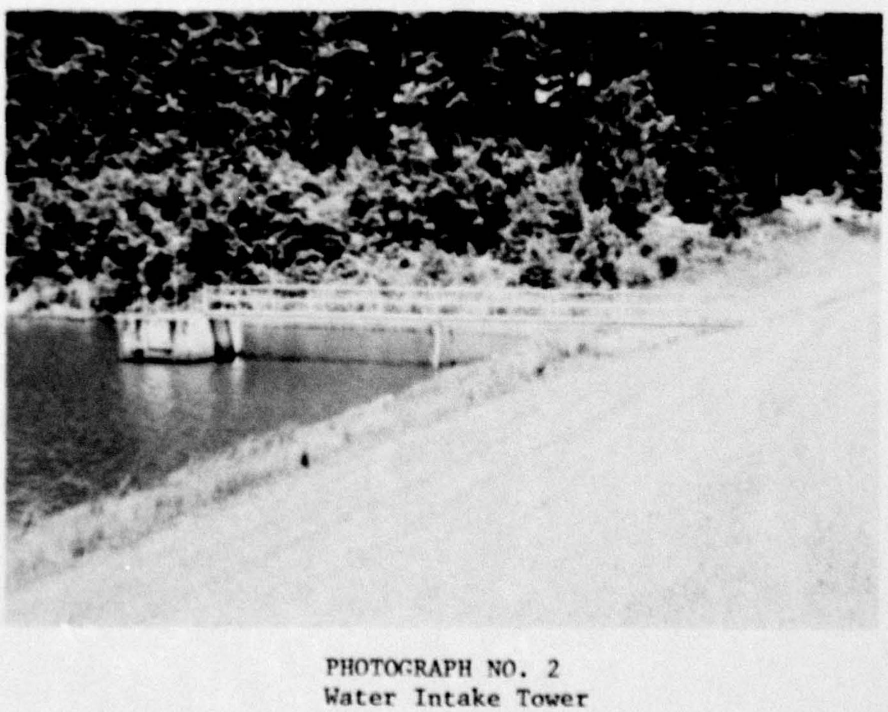
PLATE 8 NOT TO SCALE

APPENDIX II

PHOTOGRAPHS

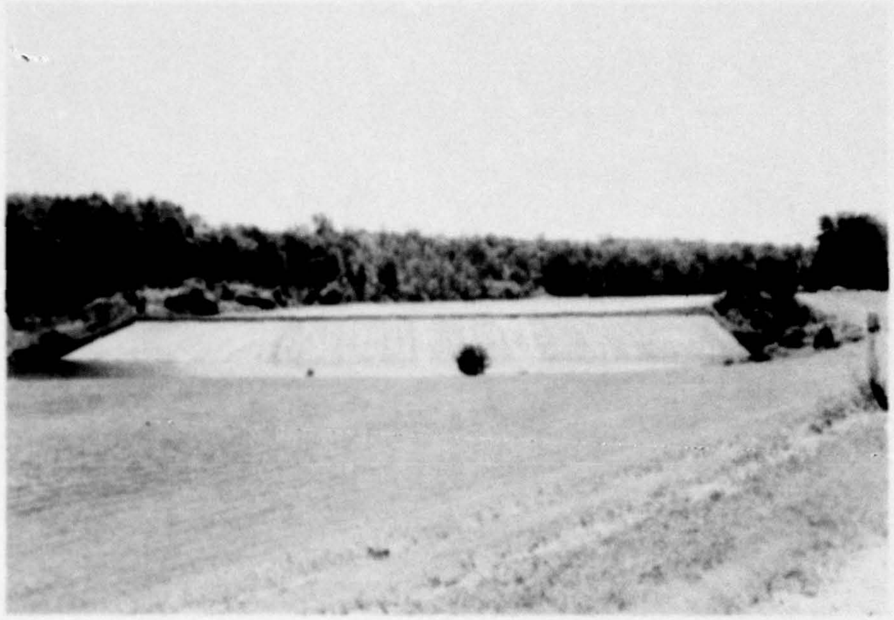
SWIFT CREEK RESERVOIR

PHOTOGRAPH NO. 1
Upstream Face



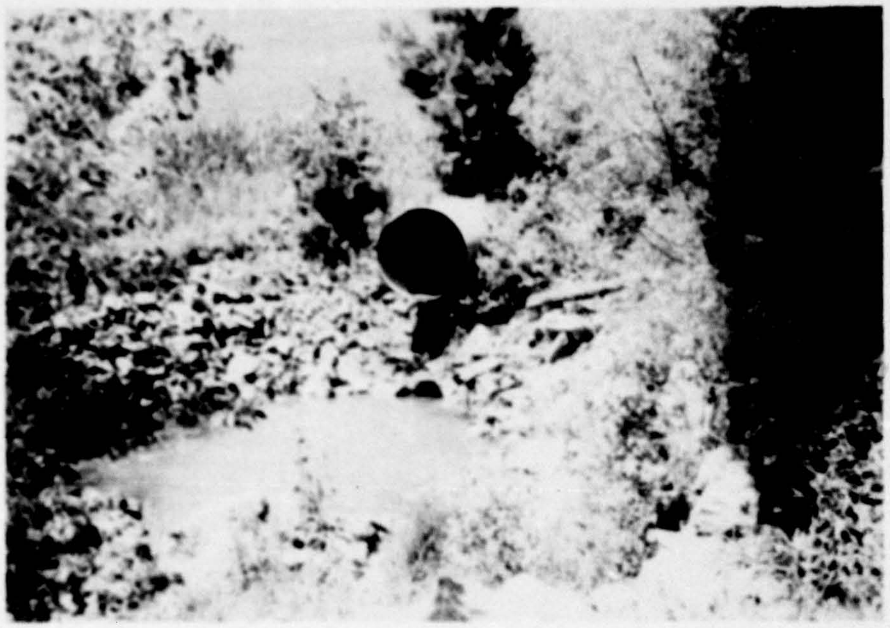
PHOTOGRAPH NO. 2
Water Intake Tower

SWIFT CREEK RESERVOIR



PHOTOGRAPH NO. 3
Concrete Spillway

PHOTOGRAPH NO. 4
Top of Spillway



PHOTOGRAPH NO. 5
60-inch Diameter Drain Outlet

PHOTOGRAPH NO. 6
Downstream

APPENDIX III

VISUAL OBSERVATIONS

Check List
Visual Inspection
Phase I

Name Swift Creek Reservoir Dam County Chesterfield State Virginia Coordinates Lat. 3725.0
Long. 7739.0

Date(s) Inspection 6/25/79 Weather Clear Temperature 70°F

Pool Elevation at Time of Inspection 177 M.S.L. Tailwater at Time of Inspection 150 M.S.L.

Inspection Personnel:

Curt Linderman , S.W.C.B. Craig Bryant, Utilities Engineer

Mike Cowell , Law Engineering Donald E. Addison, Plant Superintendent

Tan C. Young , DMM&A

Paul Seiler, DMM&A Recorder

UNGATED SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE WEIR	The general condition of the concrete surface is good. There are several slight cracks and seepages on the spillway surfact resulting from deterioration of joint material.	
APPROACH CHANNEL	N/A	
DISCHARGE CHANNEL	A stilling basin below the spillway and a 620-foot outlet channel is connected to Swift Creek. Both are in good condition.	
BRIDGE AND PIERS	No cracks observed on the spillway endwalls.	

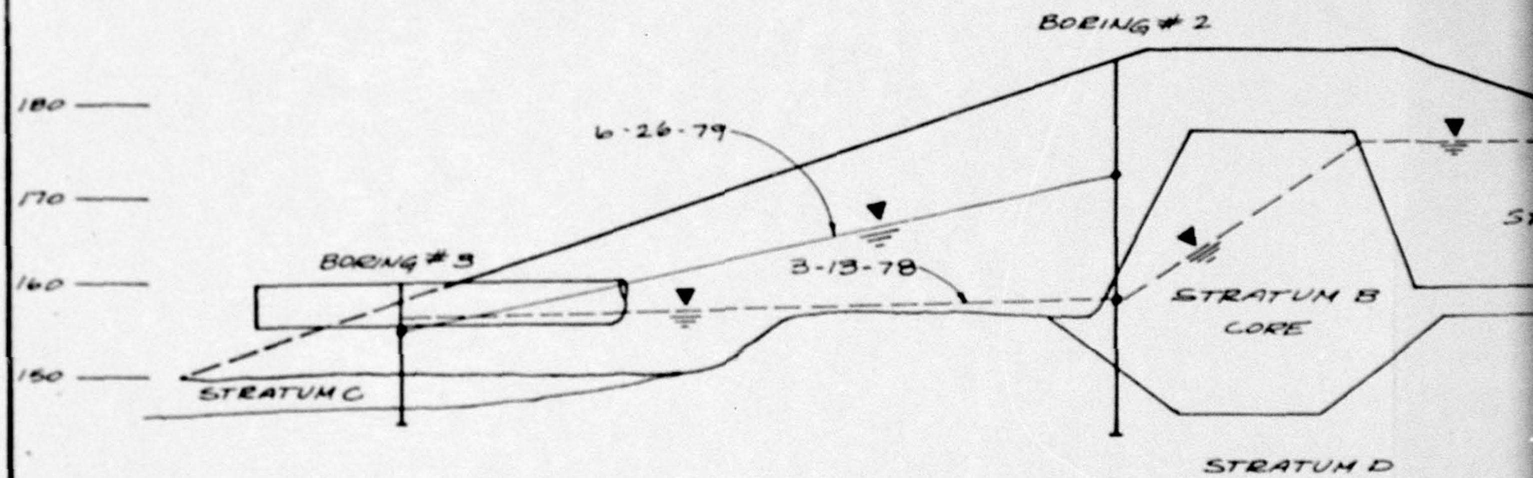
12

RESERVOIR

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	Flat, approximately 0.15%.	
SEDIMENTATION	Unknown.	

DOWNSTREAM CHANNEL

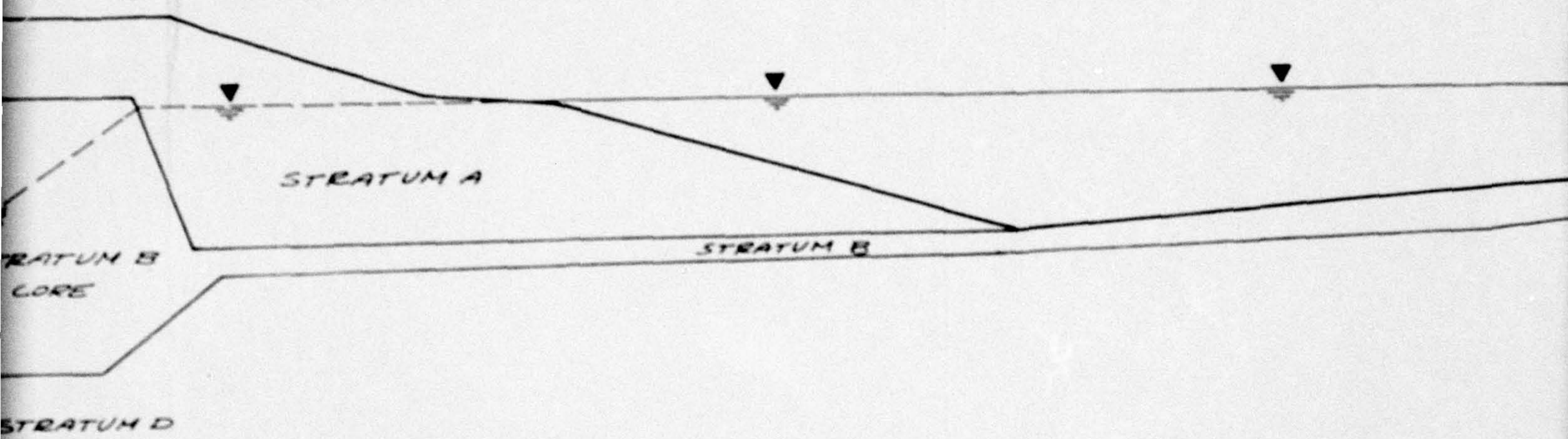
VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION (OBSTRUCTIONS, DEBRIS, ETC.)	The outlet channel from the spillway has a 100-foot botton width, 4:1 side slope and 0.5% slope to Swift Creek. The natural streambed is about 45 feet wide.	
SLOPES	Slopes in the vicinity of the dam are approximately 10 to 17%.	
APPROXIMATE NO. OF HOMES AND POPULATION	There are approximately 12 homes or 45 people within 5 miles downstream.	



	WATER LEVEL READINGS	
	3-13-78	6-26-79
BORING # 2	25' 10"	12' 0"
BORING # 3	2'-9"	4' 6"

SECTION @ 2 +

1



ECTION @ 2 + 00

PLATE NO. 1

OBSERVATION WELL READINGS	LAW ENGINEERING TESTING COMPANY GEOTECHNICAL & ENVIRONMENTAL CONSULTANTS 7913 WESTPARK DRIVE, MCLEAN, VIRGINIA 22101		
SWIFT CREEK RESERVOIR DAM	SCALE N/A	Drawn: DLR Checked: MJC Date: 7-24-79	Job No. W9-2070
CHESTERFIELD COUNTY, VIRGINIA			Dwg. No. 1

2

APPENDIX IV

PARTIAL REPORT BY J. K. TIMMONS

B. GEOTECHNICAL

1. Phase I Study

a. Introduction

Our scope of services for the Swift Creek Reservoir Dam included site inspection, review of existing design data, the drilling and logging of three test borings, soil laboratory testing, and engineering analysis. The geotechnical engineering analysis included evaluation of site inspection, test borings, soil laboratory testing, geologic and related design data to develop the following:

1. Estimated subsoil profiles and groundwater levels within the probable critical section of the Swift Creek Dam.

2. Evaluation of Swift Creek embankment material properties.

3. Stability analysis of Swift Creek Dam for maximum pool and other critical conditions developed during the study.

4. Report of findings concerning the condition of the Swift Creek Dam with respect to geotechnical engineering conditions.

This scope of work corresponds to the U.S. Army Corps of Engineers Phase I and Limited Phase II Study outlined in "Recommended Guidelines for Safety Inspection of Dam" with respect to geotechnical engineering.

The Swift Creek Reservoir Dam is located on Swift Creek about 1500 ft north of U.S. Route 360 in Chesterfield County, Virginia. The reservoir, constructed in 1965, has a surface area of about 1700 acres at normal pool level, EL 177. The dam is approximately 1100 ft in length with maximum height of about 36 ft from the former bed of Swift Creek to the top of the dam. The maximum depth at normal pool is 26 ft. The principal spillway extends to the south of the embankment with a total width of 400 ft. A 60 inch diameter drain is provided adjacent to the east abutment.

The general layout of the dam and spillway obtained from the design drawings is included on Drawing 2. This sheet also includes original topographic data. The initial inspection phase included development of the regional geology for the site and review of the existing contract drawings. This review was followed by a visual inspection of the dam.

b. Regional Geology

A brief geological study was made of the immediate area in order to determine the type of rock which underlies the dam and whether or not any faults are present. This study was performed by reviewing readily

available geologic literature and field-checking the area.

The dam appears to be underlain by the Petersburg Granite and commonly related rock such as granite gneiss, amphibolite and quartz veins. The granite is bound by Triassic-Age sandstones and shales approximately 2000 feet west of the conrete dam, in the general vicinity of Dry Creek as indicated on Sheet 1. The Virginia State geologic map describes the contact between the granite and the sandstones and shales as a northeast-southwest trending fault contact, although the presence of this fault is not indicated by the geologic map of the Richmond Basin. The fault contact is not shown to be present beneath the dam. This is further supported by the absence of faults or fault zones in the limited number of outcrops observed.

The dam is located in an area where the probability of seismic activity is low and is expected to cause only minor damage. Specifically the dam is located in a Zone 1 seismic area as defined by the Corps of Engineers.

c. Review of Available Design Data

Our review of design data was limited to the contract drawings for the project. Specifically Sheets 1 through 13 prepared by J.K. Timmons and Associates and dated May 15, 1965, were reviewed for geotechnical engineering considerations. We understand that inspection and testing of the embankment foundation subgrade and fill soils was provided during construction. However, this data was no longer available for review.

The dam is a zoned earthen embankment with a clay core. The core is designed to penetrate to rock or other suitable foundation soil. An upstream clay blanket is also provided and extends from the core to about 110 ft beyond the upstream toe to the embankment. An underdrain is provided at the downstream toe. A 60 inch diameter drain is provided along the east abutment with antiseep collars from the core to the upstream toe.

The dam side slopes are three horizontal and one vertical both upstream and downstream. However, a berm approximately 12 ft in width with a slope of 12 horizontal to one vertical was provided on the upstream slope. Thus the upstream slope is less than 3 horizontal to one vertical.

It is our opinion that the overall design concept for the embankment is in accordance with generally accepted principals of geotechnical engineering.

d. Field Inspection

1. Settlement and Slope Stability

The embankment crest and side slopes were inspected on February 21, 1978 following lowering of the pool water level to about EL 176.5 or about


SOIL MECHANICS AND FOUNDATIONS
REGIONAL GEOLOGY MAP
SWIFT CREEK
RESERVOIR DAM
CHESTERFIELD CO., VA.
SWIFT CREEK RESERVOIR
Creek
Dry Creek
Swift
TRIASSIC SANDSTONES AND SHALES
APPROXIMATE LOCATION OF FAULT LINE
PETERSBURG GRANITE
GR
GN
TRss
LEGEND
GR - GRANITE
GN - GRANITE GNEISS
TRss - TRIASSIC SANDSTONES & SHALES
SCALE

0.5 ft below normal pool level. No localized settlement, depressions or sink holes were noted. Smooth uniform slopes were observed throughout and no surface cracks were evident which would indicate immediate stability problems. However, since a design stability analysis was not available for review, we recommended a limited evaluation of the dams stability be included in this study. The results of this analysis are included in Section 2 of the report, the Phase II Study.

2. Seepage

An area of seepage was observed at the toe of the downstream slope just west of the 60 inch diameter drain as noted previously and illustrated on Photographs 1 & 2. This was the only observed seepage on the downstream face. This seepage apparently has been occuring for several years due to the presence of marsh grass and cattails in the area. We believe this seepage is related to the backfill soils along and above the 60 inch diameter drain pipe since the only source observed is located about 6 to 8 ft west of the pipe centerline. It is difficult to completely eliminate this type of seepage since the pipe is a discontinuity in the dam section. The seepage collars provided are for the purpose of increasing the length of the flow path along the pipe. Even with these seepage collars, however, some seepage is likely. Since this dam does not have a downstream drainage blanket extending back from the toe drain to allow interception of this seepage, it is draining from the area at the toe of the slope. The seepage flow is estimated at less than 1/4 gpm.

A water observation well was installed in Boring B-3, as illustrated on Photograph 3 to determine the Piezometric level in the area of the seepage. This well indicates the water level to be about 3 ft below the ground surface and is probably influenced by the drawdown effect of the toe drain. Thus it appears the seepage is being perched above the general Piezometric level. This is a further indication that the seepage is related to the spillway pipe backfill. We do not believe this seepage is a major problem at this time, however, we recommend that the area be monitored by county personnel on a quarterly Any increase in the quantity of flow or indication that soil is being eroded from the dam should be reported to us for further investigation.

3. Drainage System

A toe drainage system was provided in the design and was installed with outfall pipes adjacent to the principal spillway and the 60 inch drain. The discharge from these drains appears clear and no evidence of suspended soils washing from the interior of the dam were present. However, the central outfall toe drain, indicated on the plans, was not located. We understand this outfall drain was eliminated during construction when the amount of suitable material excavated from the dam foundation exceeded the amount estimated during design. This unsuitable material was placed along the entire toe of the dam in a downstream low area between the stream and present spillway stilling basin. Seepage entering the drain in the area of the deleted outfall was diverted to the outfall adjacent to the 60 inch pipe spillway with

a corresponding change in the directions of toe drain pipe slope. Since the outfall adjacent to the 60 inch pipe spillway is not flowing at capacity, the drain is apparently providing adequate flow capacity and the deletion of the middle outfall was not detrimental.

Existing underbrush and trees should be removed from the area of toe drain outfall pipes. Periodic maintenance should be provided to insure the drains are free flowing.

4. Slope Protection

The embankment was observed for wave and surface runoff erosion. No major erosion problems were detected. The embankment appears well maintained and continuing maintenance will prevent future erosion problems.

60

2. Phase II Study

a. Subsoil Conditions

During our initial site visit, it was noted that the downstream toe of the dam near the 60 inch diameter drain was wet indicating possible toe seepage. In order to monitor the phreatic surface through the dam at this location, two test Borings, B-1 and B-2 were drilled at about Station 2+15 at the toe and top of the dam. Water observation wells were installed to allow continued monitoring of the water level through the dam. A third test Boring, B-3 was drilled through the core 5 ft north of the dam centerline at about Station 2+95 to evaluate the confirmance of the cutoff trench and core material with design requirements. Undisturbed soil samples were obtained from all test borings to evaluate material properties.

The test borings were drilled by W.E. Dvorak, Richmond, Virginia, and logged by our personnel. The test boring logs are included in Appendix B and data are projected on the dam sections included on Drwg. 3. Based on the test borings, the following generalized soil strata underlie the site to the depths indicated:

Stratum A:	From the ground surface to depths of 9 to 23 ft (embankment shell)	Brown fine to coarse sand, FILL (SM), some clayey silt with rock fragments; fine to coarse silty clayey sand, FILL (SC), and fine to medium sandy silty clay, FILL (CL), with rock fragments; loose to firm and medium consistency (N=5 to 26)
Stratum B:	Below Stratum A to depths of 35 to 48.5 ft (embankment core)	Brown and reddish brown fine to medium sandy silty clay and sandy clay, FILL (CL-CH), with rock fragments; stiff to very stiff consistency (N=8 to 16)
Stratum C:	Below Stratum A to a depth of 14.2 ft in Boring B-3 (stream deposit)	Gray fine to coarse SAND, trace silt, with roots and organic matter (SM); loose (N=8)
Stratum D:	Below Strata B and C to the maximum depth of penetration, 48.9 ft (residual soil)	Gray disintegrated rock (SM); very compact (N=100+)

The depth of topsoil varied from 3 to 5 inches as indicated on the boring logs. N-values indicate the low and high Standard Penetration Test resistances encountered in a particular layer as determined from

the number of blows required to drive a 2 inch O.D. 1-3/8 inch I.D. sampling spoon one foot using a 140 pound hammer falling 30 inches. This test is conducted after seating the sampler six inches in the bottom of the hole according to ASTM D-1586. The disintegrated rock of Stratum D is residual material with N-values in excess of 60 blows per foot and less than 100 blows for 2 inches of penetration, which is considered refusal.

Water was not encountered during drilling in all borings. Long-term readings obtained from water observation wells indicate groundwater varies from about EL.159 at the downstream face of the core to about EL.158 at the toe of the dam. Fluctuations in the phraetic surface may result due to variations in pool level, precipitation, surface runoff, and evaporation occuring throughout the year.

b. Soil Laboratory Testing

Seven undisturbed tube samples and several jar samples were tested and data are presented in the Summary of Soil Laboratory Tests included in Appendix A. Soil classification is by the Unified System, ASTM D-2487.

1. Stratum A-Fine to coarse sand, some clayey silt (SM), silty clayey sand (SC) and sandy silty clay (CL) (embankment shell)

The soils of this stratum are variable with fines content ranging from 25 to 52 percent. Natural dry densities ranged from 122 pcf for a sand sample to 104 pcf for a clay sample. Natural moisture contents varied from 7.1 to 19.5 percent. A permability test indicated a value, $k=4.8 \times 10^{-7}$ ft/min or low.

A consolidated undrained triaxial compression test was also performed to evaluate the soils undrained shear strength. The following strength parameters were obtained:

Angle of Internal Friction, $\phi=14^{\circ}$
Cohesion, $c=750$ psf

Although drained tests were not performed, we believe the following data are reasonable for the soil types included in Stratum B

Effective Angle of Internal Friction, $\phi'=27^{\circ}$
Effective Cohesion, $c'=0$ psf

2. Stratum B-Fine to coarse sandy silty clay (CL) and sandy clay (CH) (embankment core)

The natural moisture contents of this material are generally higher than the soils of Stratum A ranging from 19.9 to 25.8 percent. The natural dry densities are correspondently lower ranging from 108 to 100 pcf. The generally higher clay content of the core material is probably responsible for the variation of these data as compared to Stratum A data. The higher clay content is also responsible for the lower permability, $k=3.0 \times 10^{-9}$ ft/min which may be considered impervious.

Undrained shear strength parameters obtained in a consolidated undrained triaxial compression test and a direct shear test are as follows:

	Triaxial Test	Direct Shear Test
Angle of Internal Friction	ϕ=19°	ϕ=23°
Cohesion	c=1500 psf	c=630 psf

The triaxial compression test data were used in our analysis.

Estimated drained strength parameters are as follows:

Effective Angle of Internal Friction	ϕ'=20°
Effective Cohesion	c'= 0 psf

c. Geotechnical Engineering Analysis

The basic design requiements included in the contract plans which were evaluated in more detail in this phase of the study included 1) the foundation conditions, 2) the material type and compaction, and 3) the geometry of the dam.

1. Foundation Conditions

The test borings drilled prior to construction define the soil types encountered, but do not include Standard Penetration Test data. These borings are included on Sheet 11 of the contract drawings. The estimated bottom of cutoff trench is also included. This data indicates the bottom of the cutoff trench to be founded on granite, weathered granite, decomposed granite or residual clay soils. The remainder of the dam was to be supported on natural ground following removal of all organic overburden.

The test borings drilled at the site for this study indicate the dam was founded on the natural disintegrated rock of Stratum C at the boring locations, as specified. These soils were derived by in-place weathering of the underlying Petersburg granite rock. A 3.5 ft layer of sand, probably the former stream bed of Swift Creek was encountered in Boring B-3. However, the more important cutoff trench area, penetrated by Boring B-1, and also located in the former Swift Creek bed, indicated all stream deposits had been removed to disintegrated rock as required. The foundation and as-built conditions as indicated by the test borings are in our judgment satisfactory and in conformance with standard geotechncial engineering practice.

2. Material and Compaction Requirements

The contract drawing indicate the embankment shell was to be constructed of residual soil from the spillway excavation and that all soils were to be compacted to 95% of maximum dry density according to ASTM D-1557 (Modified Proctor). The embankment core was to be imported clay with the same degree of compactive effort required during placement. The shell and core soils have been designated Strata A and B respectively

for purposes of this study.

Natural densities obtained from "undisturbed" tube samples appear to indicate a slightly lower density range than would be required to meet the specifications. This is probably due to the disturbance associated with obtaining and testing this type of sample, especially since the soils contain rock fragments.

We understand that full-time inspection of fill installation was provided during construction and thus we believe it is not necessary to evaluate this further.

Classification tests indicate Stratum A materials to range from SC to CH. The permeability of one sample from this stratum was very low at $k=4.8 \times 10^{-7}$ ft/min. From a permeability standpoint, this soil is excellent. Stratum B soils in the core were found to be silty clays and clays classified CL and CH respectively and corresponding to the design requirements. The permeability data presented previously indicated the soil is essentially impervious with a permeability of 3.0×10^{-9} ft/min. This is an excellent core material.

3. Geometry of Dam

The clay core was penetrated by both Boring B-1 and B-2 and was found to conform generally with the contract drawing. The core is slightly wider than recommended at Station 2+15 where Boring B-2 was drilled as illustrated on Drwg. 3. This a positive factor with respect to seepage through the dam. The top of the core at Boring B-1, Station 2+95, extends to only about EL 179 or about 9 ft below the embankment crest. The original contract drawings indicate the core was to be constructed to the top of the dam, EL 187. For purposes of this study, we have assumed this change was made during construction. Since the shell and core material are similar and both have low permeability, this change is not considered to be a problem with respect to continued dam performance.

We understand further that excess material excavated from the dam foundation was placed at the downstream toe. This additional fill increases the factor of safety with respect to slope failure.

A stability analysis was performed for the two most critical conditions 1) sudden drawdown of pool to creek level for the upstream face and 2) steady seepage for the downstream slope. These are designated Cases I and III by the Corps of Engineers. The strength parameters described previously were used in this analysis along with the dam geometry indicated on Section 2+00, Drwg. 3. Since the dam is located in an area where the probability of seismic activity is low, earthquakes were not taken into account in our stability analysis.

The minimum factor of safety for the steady seepage, Case III was found to be 1.5, this condition occurs for the critical potential shear circle indicated on Drwg. 3. For Case I, the minimum factor of safety was obtained with a deep circle and was about 3.0. These factors of safety are adequate for the cases considered.

3. Conclusions and Recommendations

Based on the geotechnical engineering data contained in this report, the following summary of conclusions and recommendations is presented:

a. The Swift Creek Reservoir Dam contract drawings were reviewed for conformance with generally accepted principles of geotechnical engineering. We believe the design is suitable for the site foundation conditions and materials utilized. However, the construction inspection reports related to the observation of the dam foundation and cutoff trench subgrades and testing of shell and core soil compaction were not available.

b. The dam was inspected using the U.S. Army Corps of Engineers guidelines for settlement and slope stability, seepage, drainage systems and slope erosion problems. Although no major problems were observed, one area of seepage was located at the downstream toe just west of and adjacent to the 60 inch diameter drain.

c. Since construction inspection data were not available and a small area of seepage was located, we have included a limited Phase II Study to evaluate the conformance of the embankment soils with criteria included on the design drawings. This study included drilling three test borings, installing two permanent water observation wells to allow present and future monitoring of the water level through the dam, laboratory testing and engineering analysis.

d. The Phase II Study indicates general conformance of the dam properties and geometry with those specified in the contract drawings. The test boring data illustrates the core trench and remainder of the dam foundation corresponds to the requirements of the design drawings at the points investigated. Laboratory test data indicate the core material is silty clay and clay with very low permeability and that this material meets design requirements.

e. The water observation wells indicate the water level through the downstream slope of the embankment varies from about EL 159 at the edge of the core to EL 158 at the downstream toe. These data indicate the embankment core and the toe drain are performing as planned. Both water observation wells should however be monitored periodically to determine any major variation from the water level depths shown on the test boring logs. (B-2 25'10"and B-3 2'9")

f. A stability analysis was performed using shear strength data developed in the soils laboratory and dam geometry to determine the factor of safety of the embankment with respect to shear failure.

Case	Loading Condition	Factor of Safety
I	Sudden drawdown of reservoir (upstream slope)	3.0
III	Steady seepage (downstream slope)	1.5

These factors of safety are acceptable and indicate the embankment is stable under present loading conditions.

g. The water observation well adjacent to the area of seepage indicates the phreatic level is 4 ft below the embankment surface. This indicates the seepage observed on the downstream toe is perched above the general phreatic surface. We believe this seepage is related to the drain pipe and may be the result of minor flow along the outside of the pipe. Although this is not a serious problem, we recommend that the seep be observed on a quarterly basis to determine any changes in the quantity of flow or the presences of suspended soils eroding from the embankment.

h. We have prepared this report in accordance with generally accepted principles of soil and foundation engineering practices, and make no other warranties, either expressed or implied, as to the professional advice provided under the terms of this agreement and included in this report.

SUMMARY OF SOIL LABORATORY TESTS

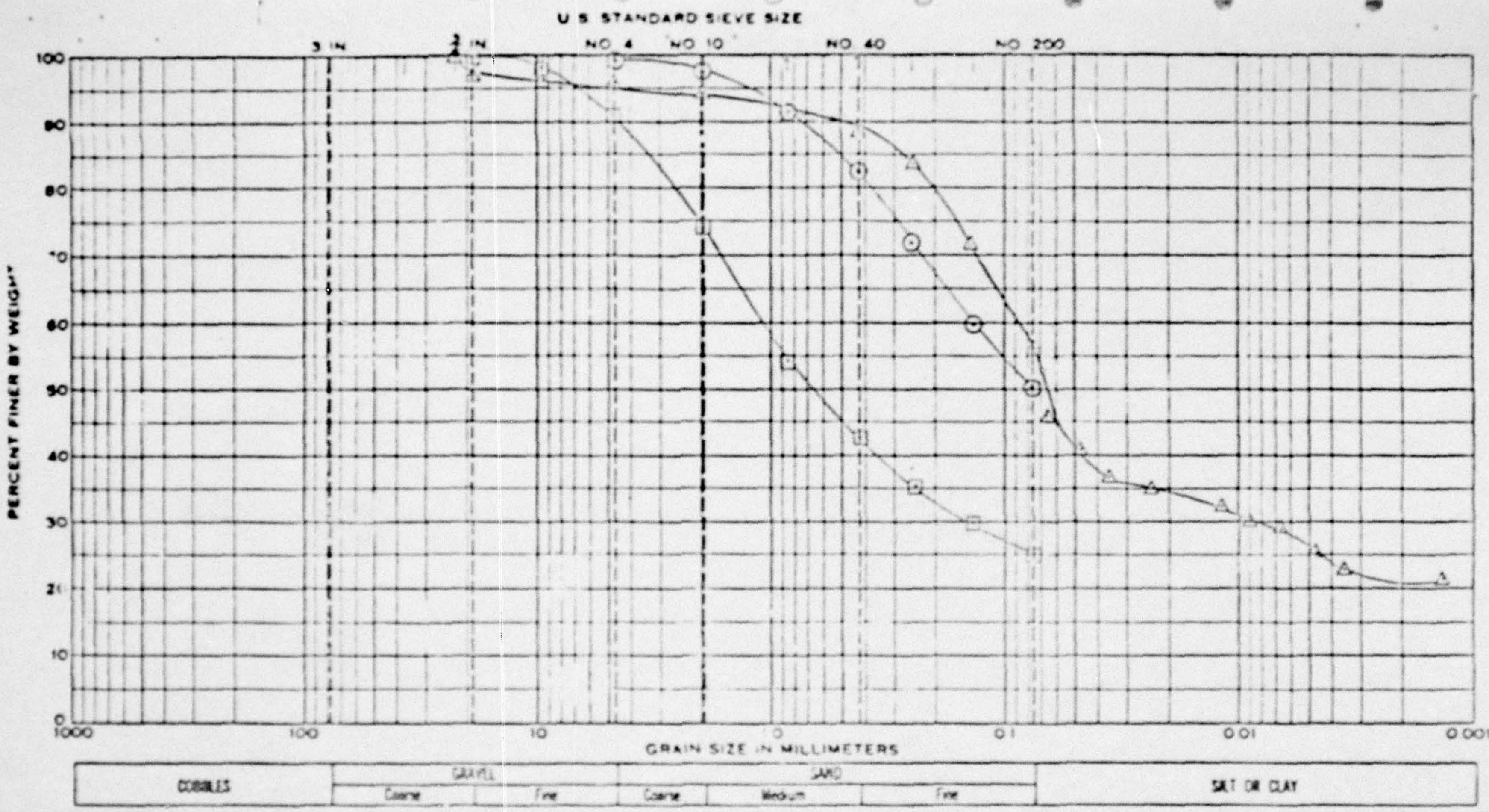
Location	Boring No.	Sample Depth / Elev.	Sample Type	Description of Soil Specimen	Stratum Designation	Natural Density pcf		Natural Moisture %	Atterberg Limits			Laboratory Permeability (ft/min)	% Finer than #200 Sieve	Shear Strength	Specific Gravity	Remarks
						Wet	Dry		L.L.	P.L.	P.I.					
SWIFT CREEK DAM	B-1	8' / 179.5	3 inch tube	Fine to medium sandy silty clay, fill, with rock fragments-brown (CL)	B	124	100	23.9	40	20	20	-	50	-	-	See gradation test curve
		18' / 169.5	3 inch tube	Fine to medium sandy silty clay, fill, with rock fragments-brown (CL)	B	126	104	21.0	34	14	20	-	60	$\phi=19^{\circ}$ c=1500 psf	-	See triaxial compression test curve
		28' / 159.5	3 inch tube	Fine to coarse sandy silty clay, fill, with rock fragments-brown and gray (CL)	B	130	108	19.9	39	13	26	k= 3.0×10^{-9} (ft/min)	57	$\phi=23^{\circ}$ c=630 psf	2.63	See combined mechnical analysis and direct shear test curves
		36' / 151.5	Jar Sample	Fine sandy clay fill-reddish brown (CH)	B	-	-	25.8	64	20	44	-	62	-	-	
	B-2	7.5' / 177.5	3 inch tube	Fine to coarse sand fill, some clayey sand and rock fragments brown (SM)	A	130	122	7.1	37	26	11	k= 4.8×10^{-7} (ft/min)	25	-	-	See gradation test curve
		17.5' / 167.5	3 inch tube	Fine to coarse silty clayey sand, fill, trace rock fragments-brown (SC)	A	132	113	16.3	37	17	20	-	49	-	2.49	See combined mechnical analysis test curve
		27.5' / 157.5	Jar Sample	Fine sandy clay fill-reddish brown (CH)	B	-	-	24.8	61	27	34	-	56	-	-	See gradation test curve
	B-3	9' / 152.0	3 inch tube	Fine sandy silty clay, fill-brown and gray (CL)	A	124	104	19.5	36	14	22	-	52	$\phi=14^{\circ}$ c=750 psf	2.64	See combined mech. analysis & triaxia test curve
F.C.D.	Bulk 1	0-1'	Bulk	Fine to coarse sand, fill, some silty clay, trace gravel -brown (SC)		-	-	-	26	15	11	-	25	-	-	See gradation test curve

NOTE: 1. Soil tests in accordance with applicable ASTM Standards.

2. Soil classification in accordance with Unified Soil Classification

3. Key to abbreviations: LL=Liquid Limit; PL=Plastic Limit; PI=Plasticity Index; F.C.D.=Falling Creek Dam

4. Soil Tests were conducted by R. Harris, J. Hollowell and



KEY	BORING	DEPTH	DESCRIPTION OF SOIL SAMPLE TESTED	CLASSIF	M.C.	LL	PI
⊙	B1	8	FINE TO MEDIUM SANDY SILTY CLAY, FILL, WITH ROCK FRAGMENTS - BROWN	CL	23.9	40	20
△	B-1	28'	FINE TO COARSE SANDY SILTY CLAY, FILL, WITH ROCK FRAGMENTS - BROWN & GRAY	CL	19.9	39	26
☐	B-2	7.5	FINE TO COARSE SAND, FILL, SOME CLAYEY SILT AND ROCK FRAGMENTS - BROWN	SM	7.1	37	11

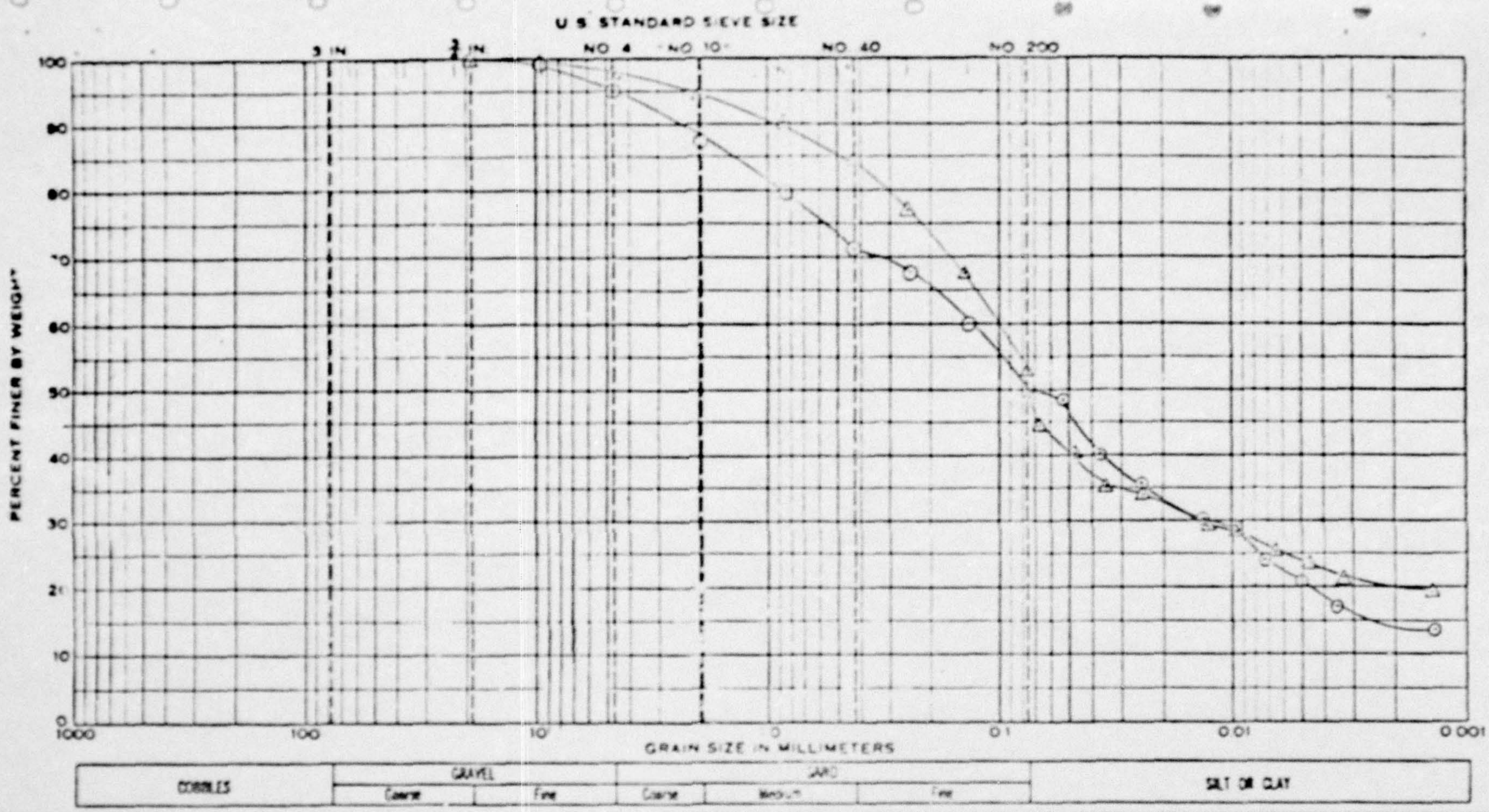
SCHNABEL ENGINEERING ASSOCIATES

GRADATION CURVES

PROJECT: SWIFT CREEK DAM

CHESTERFIELD CO. VIRGINIA

DATE: MARCH 3, 1978 CONTR. NO.: V17642



KEY	BORING	DEPTH	DESCRIPTION OF SOIL SAMPLE TESTED	CLASSIF.	M.C.	LL	PI
○	B-2	17.5'	FINE TO COARSE SILTY CLAYEY SAND, FILL, TRACE ROCK FRAGMENTS - BROWN	SC	16.3	37	20
△	B-3	9'	FINE TO COARSE SANDY SILTY CLAY, FILL - BROWN & GRAY	CL	15.5	36	22

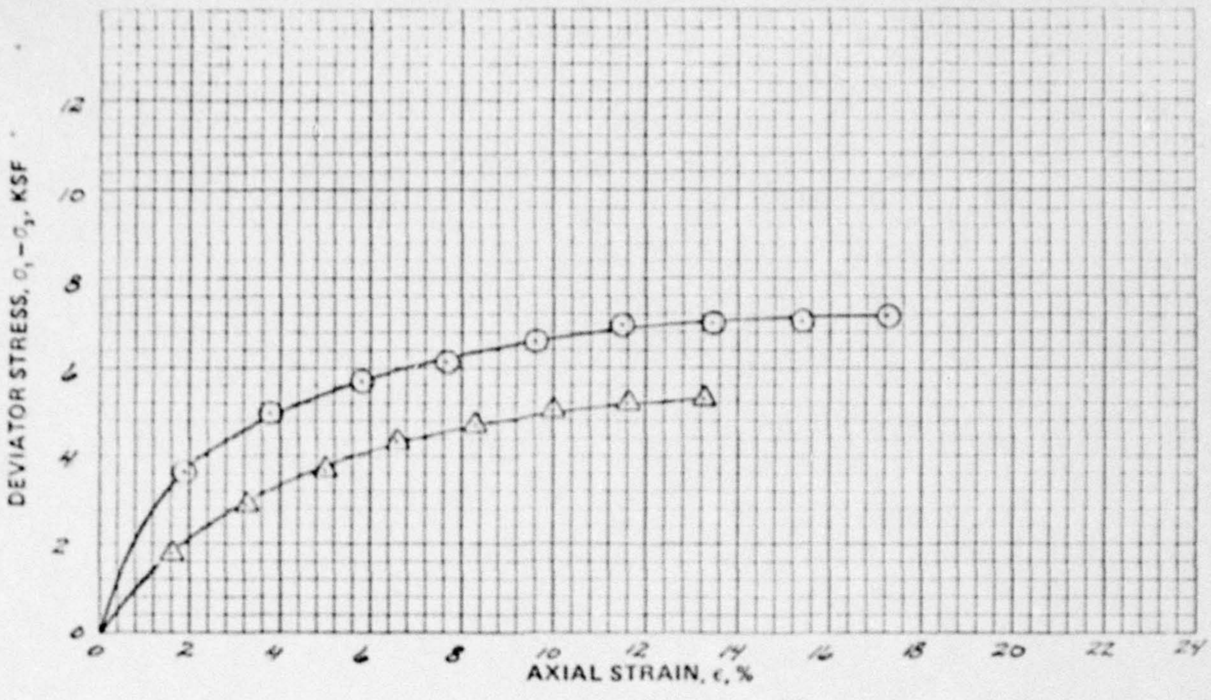
SCHNABEL ENGINEERING ASSOCIATES

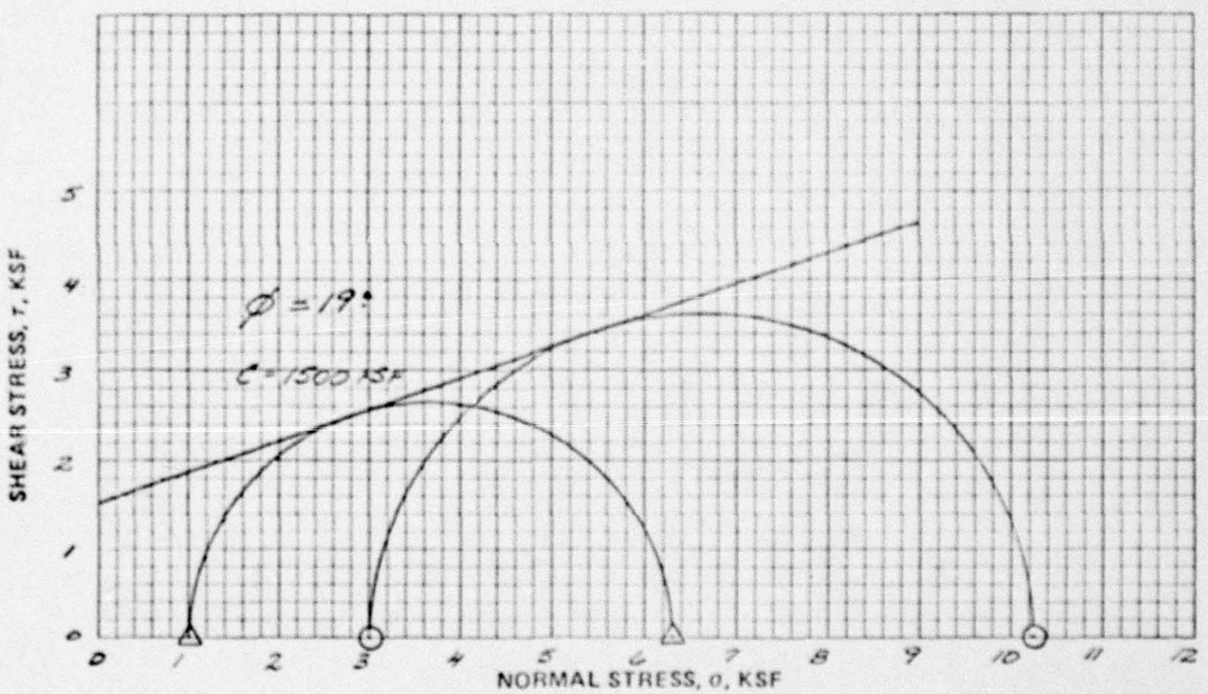
GRADATION CURVES

PROJECT: SWIFT CREEK DAM

CHESTERFIELD CO., VIRGINIA

DATE: MARCH 5 1978 | CONTR. NO. [illegible]





DESCRIPTION OF SOIL SAMPLE TESTED STRATUM B

FINE TO MEDIUM SANDY SILTY CLAY, FILL, WITH ROCK FRAGMENTS - BROWN (CL)

KEY	BORING NO.	DEPTH FT.	LATERAL PRESS.	MOIST. CONT. % INITIAL	MOIST. CONT. % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET
△	1	18.0	1.0 KSF	21.0	-	104	126
⊙	1	18.0	3.0 KSF	21.0	-	104	126

SCHNABEL ENGINEERING ASSOCIATES 70

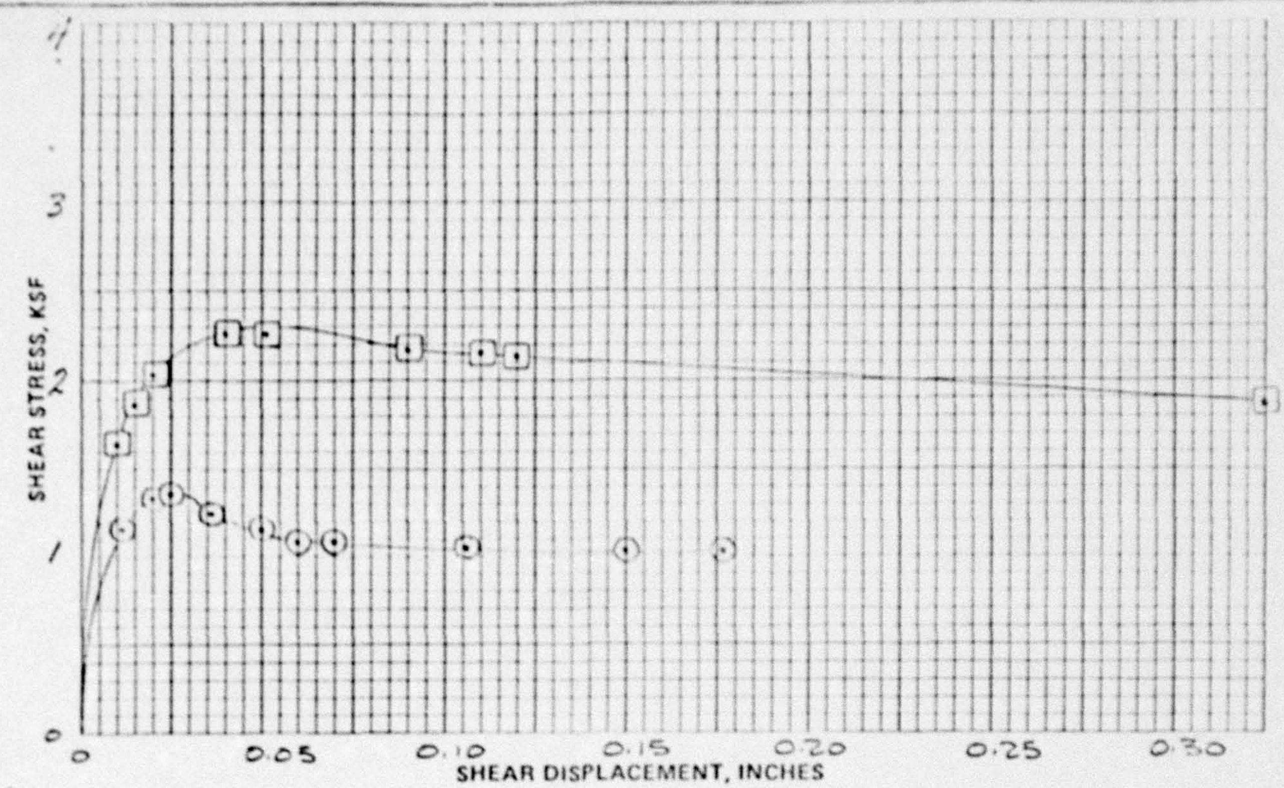
TRIAXIAL COMPRESSION TEST

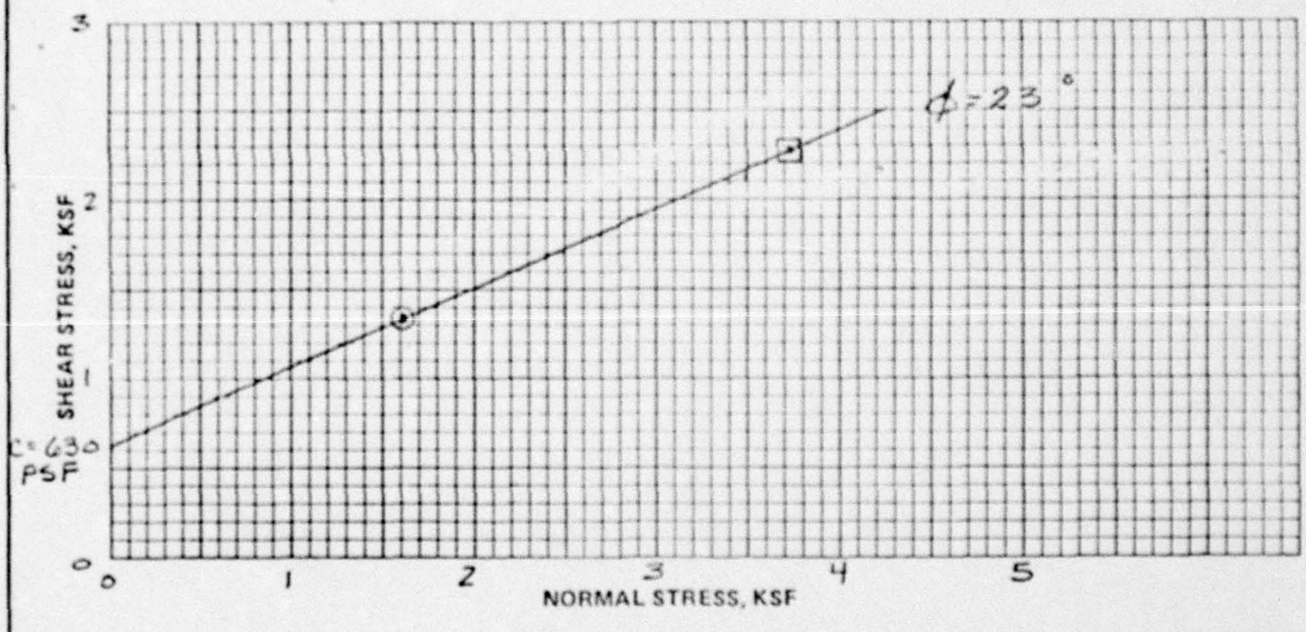
TYPE OF TEST: CONSOLIDATED - UNDRAINED

RATE OF SHEAR: 1% PER MINUTE

PROJECT: SWIFT CREEK DAM

CHESTERFIELD CO, VA





DESCRIPTION OF SOIL SAMPLE TESTED — STRATUM B

FINE TO COARSE SANDY SILTY CLAY, FILL, WITH ROCK FRAGMENTS - BROWN AND GRAY (CL)

KEY	BORING NO.	DEPTH FT.	NORMAL STRESS	MOIST. CONT. % INITIAL	MOIST. CONT. % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET
⊙	1	28'	1.0 KSF	19.9	-	108	130
⊡	1	28'	3.0 KSF	19.9	-	108	130

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DIRECT SHEAR TEST

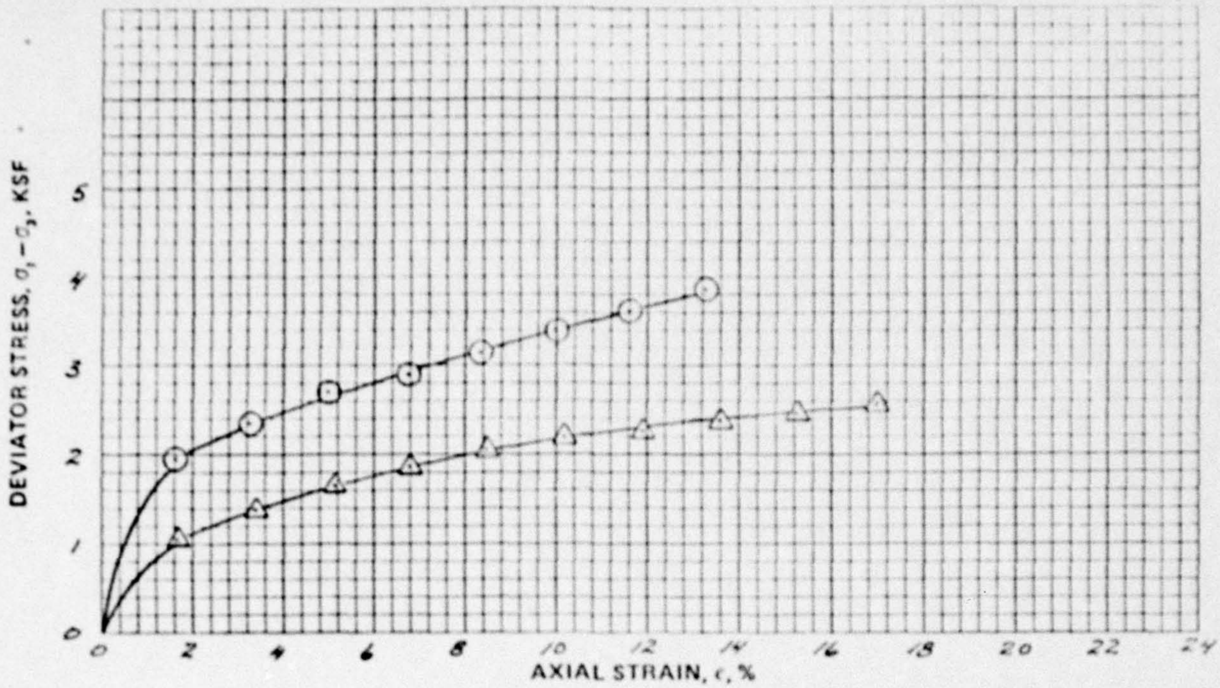
TYPE OF TEST: CONSOLIDATED,

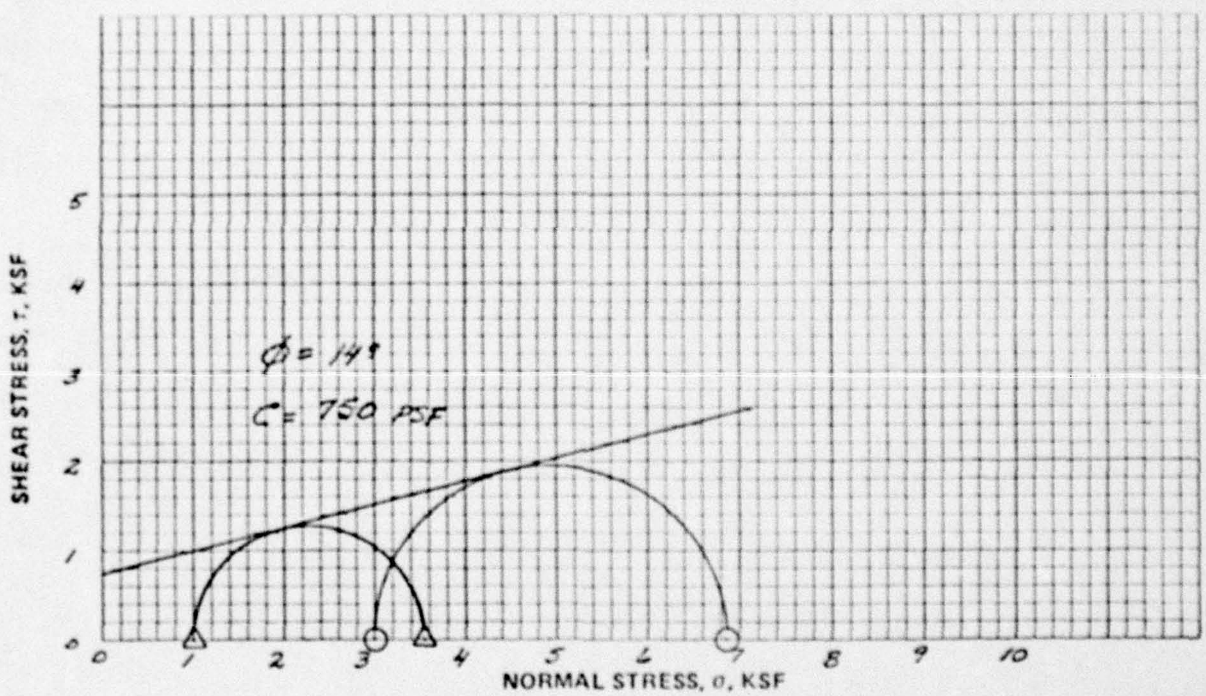
RATE OF SHEAR: 0.8 % PER HOUR

PROJECT: SWIFT CREEK DAM

CHESTERFIELD CO., VIRGINIA

DATE | CONTR. NO. [illegible]





DESCRIPTION OF SOIL SAMPLE TESTED STRATUM A

FINE TO COARSE SANDY SILTY CLAY, FILL - BROWN & GRAY (CL)

KEY	BORING NO.	DEPTH FT.	LATERAL PRESS.	MOIST. CONT. %		DENSITY, PCF	
				INITIAL	FINAL	DRY	WET
△	3	9.0	1.0 KSF	19.5	-	104	124
⊙	3	9.0	3.0 KSF	19.5	-	104	124

SCHNABEL ENGINEERING ASSOCIATES

TRIAXIAL COMPRESSION TEST

TYPE OF TEST: CONSOLIDATED - UNDRAINED

RATE OF SHEAR: 1% PER MINUTE

PROJECT: SWIFTCREEK DAM

CHESTERFIELD CO., VA

DATE: [illegible] CONTR. NO.: V78045

SUBSURFACE EXPLORATION DATA

General Notes for Test Boring Logs

Identification of Soil Samples

Test Boring Logs, B-1 through B-3

Hollow Stem Auger Borings

All borings were drilled by hollow stem auger equipment. The Standard Penetration Test (SPT) was performed at the depths indicated on the Test Boring Logs. The augers were advanced to the desired depth with plug inserted, and the SPT was performed. Water level data is indicated on the logs. Undisturbed tube samples were pressed hydraulically.

Boring Location and Elevation Survey

Test borings were located as shown on Sheet 1. These borings were located by taping from the existing site features. Boring locations should be considered accurate to 3 ft±. Testing boring elevations were estimated from available topographic data.

GENERAL NOTES FOR TEST BORING LOGS

1. NUMBERS IN "SAMPLE SPOON" COLUMN INDICATE BLOWS REQUIRED TO DRIVE A 2 INCH O.D., 1-3/8 INCH I.D. SAMPLING SPOON 6 INCHES USING A 140 POUND HAMMER FALLING 30 INCHES ACCORDING TO ASTM D-1586.

2. VISUAL CLASSIFICATION OF SOIL IS IN ACCORDANCE WITH TERMINOLOGY SET FORTH IN "VISUAL IDENTIFICATION OF SAMPLES." THE UNIFIED SOIL CLASSIFICATION SYMBOLS SHOWN IN PARENTHESES ARE BASED ON VISUAL INSPECTION.

3. ESTIMATED GROUNDWATER LEVELS INDICATED BY ▼; THESE LEVELS ARE ONLY ESTIMATES FROM AVAILABLE DATA AND MAY VARY WITH PRECIPITATION, POROSITY OF THE SOIL, SITE TOPOGRAPHY, ETC.

4. REFUSAL AT THE SURFACE OF ROCK, BOULDER, OR OBSTRUCTION IS DEFINED AS A PENETRATION RESISTANCE OF 100 BLOWS FOR 2 INCHES PENETRATION OR LESS.

5. THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND AT THE PARTICULAR TIME WHEN DRILLED. SOIL CONDITIONS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO, THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE SUBSURFACE SOIL AND GROUNDWATER CONDITIONS AT THESE BORING LOCATIONS.

6. THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL AND ROCK TYPES AS DETERMINED FROM THE DRILLING AND SAMPLING OPERATION. SOME VARIATION MAY ALSO BE EXPECTED VERTICALLY BETWEEN SAMPLES TAKEN. THE SOIL PROFILE, WATER LEVEL OBSERVATIONS AND PENETRATION RESISTANCES PRESENTED ON THESE BORING LOGS HAVE BEEN MADE WITH REASONABLE CARE AND ACCURACY AND MUST BE CONSIDERED ONLY AN APPROXIMATE REPRESENTATION OF SUBSURFACE CONDITIONS TO BE ENCOUNTERED AT THE PARTICULAR LOCATION.

7. BORING LOG VERTICAL SCALE: 1/8 INCH = 1 FT.

8. TEST BORINGS DRILLED BY W. E. DVORAK, RICHMOND, VIRGINIA UNDER INSPECTION OF SCHNABEL ENGINEERING ASSOCIATES.

9. KEY TO SYMBOLS AND ABBREVIATIONS:

S	STANDARD PENETRATION TEST
2"	2" or 3" UNDISTURBED TUBE SAMPLE (RECOVERY SHOWN IN REMARKS COLUMN)
	PRESSUREMETER TEST
V	VANE SHEAR TEST
C	STATIC CONE PENETRATION TEST
2"	NX OR 2 INCH O.D. ROCK CORE RUN (RECOVERY SHOWN IN REMARKS COLUMN)

*,	NO SAMPLE RECOVERY
do,	DITTO
RQD,	ROCK QUALITY DESIGNATION
w,	NATURAL MOISTURE CONTENT

SCHNABEL ENGINEERING ASSOCIATES

Consulting Geotechnical Engineers

IDENTIFICATION OF SOIL

I. DEFINITION OF SOIL COMPONENTS

Major Material Component	Material Fraction	Sieve Size	Plasticity
GRAVEL, GM, GC, GP, GW	Coarse Fine	3/4 to 3" No. 4 to 3/4	– –
SAND, SM, SC, SP, SW	Coarse Medium Fine	No. 10 to No. 4 No. 40 to No. 10 No. 200 to No. 40	– – –
SILT, ML	–	Passing No. 200	Non-plastic
CLAYEY SILT, ML, MH, CL ML	–	Passing No. 200	Slight to High
SILTY CLAY, CL	–	Passing No. 200	Medium to High
CLAY, CH	–	Passing No. 200	Very High
ORGANIC SILT, OH, OL	–	Passing No. 200	Slight to High
PEAT, Pt	Partially decomposed fibrous organic matter with or without silt or sand filter		

II. DEFINITION OF COMPONENT PROPERTIES

Component	Proportions of Soil Components	Approximate Percentage by Weight
Major	Noun Form Gravel, Sand, Silt, Clay, etc.	50 or more
Minor	Adjective Form Gravelly, Sandy, Silty, Clayey Silty, Clayey, Silty Clayey	35 to 50
	Some Some Gravel, Some Silt, etc.	12 to 35
	Trace Trace Gravel, trace sand, etc.	1 to 12
	With with rock fragments, with organic matter, etc.	indicates presence only

III. GLOSSARY OF MISCELLANEOUS TERMS

SYMBOLS – Unified Soil Classification Symbols are shown in major material component column. Use A Line Chart for laboratory identification.

BOULDERS – Rounded pieces of rock larger than 3 inches

DISINTEGRATED ROCK – Residual soil with a standard penetration resistance of at least 60 blows or more per foot

ROCK FRAGMENTS – Angular pieces of rock, distinguished from transported gravel, which have separated from original vein or strata and are present in a soil matrix.

QUARTZ – A hard silica mineral often found in residual soils

IRONITE – Iron oxide deposited within a soil layer forming cemented deposits

CEMENTED SAND – Usually localized rock-like deposits within a soil stratum composed of sand grains cemented by calcium carbonate or other minerals

MICA – A soft silica mineral found in many rocks, and in residual or transported soils derived therefrom

FISSURED CLAYS – Cohesive soils exhibiting a joint structure

ORGANIC MATERIAL (Excluding Peat): Top Soil – Surface soils that support plant life and which contain considerable amounts of organic matter; Decomposed Vegetation – Partially decomposed organic matter which retains its original character; Lignite – Decomposed organic matter with low fixed carbon content frequently exhibiting distinct texture of wood

FILL – Man made deposit containing soil, rock and often foreign matter

PROBABLE FILL – Soils which contain no visually detectable foreign matter but which are suspect with respect to origin

LENSES – 0 to 1/2 inch layer of minor soil component

LAYERS – 1/2 to 12 inch layers of minor soil component

POCKET – Discontinuous pocket of minor soil component

COLOR SHADES – Light or dark to indicate substantial differences in color

MOISTURE CONDITIONS – Wet, moist, or dry to indicate visual appearance of specimen

SCHNABEL ENGINEERING ASSOCIATES CONSULTING ENGINEERS	TEST BORING LOG	BORING NO. B-1

PROJECT: SWIFT CREEK DAM, CHESTERFIELD COUNTY, VIRGINIA
CLIENT: Chesterfield County
BORING CONTRACTOR: W.F. DVORAK
DRILL: B-41

WATER LEVEL DATA	DATE	TIME	DEPTH	CAVED
ENCOUNTERED	2/10	4:00	44'	-
AFTER CASING PULLED	2/10	4:45	26'	38'
__ HR. READING	BACKFILL UPON COMPLETION			

DRIVE	SAMPLER
TYPE	S.S.
DIA.	2" O.D.
WT.	140#
FALL	30"

SHEET NO. 1 OF 1
JOB NO.: V78045
ELEVATION: 187.5±
CASING SIZE: 3½"
DATE START: 2/10/78
DATE FINISHED: 2/10/78
DRILLER: W. DVORAK
INSPECTOR: B. HARRINGTON

STRATUM	DEPTH FT.	ELEV 187.5	BLOWS ON SAMPLE SPOON PER 6"	SYMBOL	IDENTIFICATION (3" GRAVEL)	REMARKS
			15+10+8+11	S	FINE TO COARSE SAND, FILL, SOME CLAYEY SILT, MOIST-BROWN (SM)	EMBANKMENT SHELL
			10+9+11+13	S		
A			6+4+5+7	S		
		180	5+7+9+11	S		
	9.0			3"		Tube Pressed 24" Recovery=24"
			4+5+6+8	S		
			3+4+6+8	S		
			4+4+6+8	S		
		170	3+6+8+9	S	FINE TO MEDIUM SANDY SILTY CLAY, FILL, WITH ROCK FRAGMENTS, MOIST-REDDISH BROWN TO BROWN (CL)	Tube Pressed 24" Recovery=24"
			5+7+9+11	S		
			3+4+8+11	S		
			3+6+7+8	S	do-SOME FINE TO COARSE SAND WITH ORGANIC MATTER	
		160	2+6+7+8	S	do-LIGHT BROWN	
B				3"		Tube Pressed 24" Recovery=24"
			4+4+5+8	S	do-LIGHT BROWN	
			2+4+8+8	S		EMBANKMENT CORE
	35.0		4+6+8+9	S		
		150	3+5+7+9	S	FINE SANDY CLAY FILL, MOIST-REDDISH BROWN (CH)	
			2+6+10+10	S		
			4+5+7+7	S		
			2+3+5+7	S	do-WET	
			2+5+6+8	S		
		140	4+4+5+5	S		
D	48.[illegible] 48.9		10+100/5"	S	DISINTEGRATED ROCK, WET-GRAY (SM)	
					BORING TERMINATED @ 48.9 FT	

SCHNABEL ENGINEERING ASSOCIATES CONSULTING ENGINEERS	TEST BORING LOG	BORING NO B-2

PROJECT: SWIFT CREEK DAM, CHESTERFIELD COUNTY, VIRGINIA
CLIENT: Chesterfield County
BORING CONTRACTOR: W.E. DVORAK
DRILL: B-41

SHEET NO. 1 OF 1
JOB NO.: V78045
ELEVATION: 185.0±
CASING SIZE: 3½"
DATE START: 2/9/78
DATE FINISHED: 2/9/78
DRILLER: W. DVORAK
INSPECTOR: B. HARRINGTON

WATER LEVEL DATA	DATE	TIME	DEPTH	CAVED
ENCOUNTERED	2/9	3:30	37'	-
AFTER CASING PULLED	2/9	4:00	41'	-
HR. READING	SEE	TABLE	BELOW	

DRIVE	SAMPLER
TYPE	S.S.
DIA.	2" O.D.
WT.	140#
FALL	30"

STRATUM	DEPTH FT.	ELEV 185.0±	BLOWS ON SAMPLE SPOON PER 6"	SYMBOL	IDENTIFICATION	REMARKS
					5" TOPSOIL	
			1+2+3	S	FINE TO MEDIUM SILTY CLAYEY SAND FILL, MOIST-BROWN (SC)	EMBANKMENT SHELL
	2.0					
			4+4+4	S	FINE TO COARSE SAND, FILL, SOME CLAYEY SILT AND ROCK FRAGMENTS, MOIST-BROWN (SM)	4'-5' DIFFICULT DRILLING-ROCK FRAGMENTS
		180				
				3"		TUBE PRESSED 24" RECOVERY-17"
			5+4+6	S		
A			3+13+13	S		13'-14' DIFFICULT DRILLING -ROCK FRAGMENTS
		170				
	19.0			3"		TUBE PRESSED 24" RECOVERY=24"
			4+5+6	S	FINE SILTY CLAYEY SAND FILL, MOIST-GRAY (ML)	
	22.0					
			3+4+7	S	FINE TO MEDIUM SAND FILL, SOME SILT-MOIST BROWN (SM)	
	23.5				CLAY, FILL, SOME FINE SAND, MOIST-REDDISH BROWN (CH)	
		160 ▼				
B			3+4+6	S		EMBANKMENT CORE
	30.0				SILTY CLAY, PROBABLE FILL, SOME FINE SAND, MOIST-GRAY (CL)	
			3+5+9	S		
	35.0	150				
						RESIDUAL SOIL
D				3"		TUBE PRESSED 14" RECOVERY=10"
			35+65	S	DISINTEGRATED ROCK, WET-GRAY (SM)	
	41.8		100/0"			REFUSAL

BORING TERMINATED @ 41.8 FT

WATER OBERVATION WELL INSTALLED 2/10/78

WATER LEVEL READINGS

Date	Time	Depth
2/10/78	11:00 a.m.	27' 0"
2/10/78	4:45 p.m.	25' 4"
2/13/78	7:45 a.m.	26' 0"
2/24/78	1:00 p.m.	27' 3"
3/13/78	1:00 p.m.	25' 10"

SCHNABEL ENGINEERING ASSOCIATES CONSULTING ENGINEERS	TEST BORING LOG	BORING NO. B-3

PROJECT: SWIFT CREEK DAM, CHESTERFIELD COUNTY, VIRGINIA							SHEET NO. 1 OF 1
CLIENT: Chesterfield County							JOB NO.: V78045
BORING CONTRACTOR: W.F. DVORAK					DRILL: B-41		ELEVATION: 161.0±
WATER LEVEL DATA					DRIVE	SAMPLER	CASING SIZE: 3½"
	DATE	TIME	DEPTH	CAVED	TYPE	S.S.	DATE START: 2/13/78
ENCOUNTERED	2/13	9:45	9.0'	-	DIA.	2" O.D.	DATE FINISHED: 2/13/78
AFTER CASING PULLED	2/13	11:00	5.0'	-	WT.	140#	DRILLER: W. DVORAK
__ HR. READING	SEE	TABLE	BELOW		FALL	30"	INSPECTOR: R. HARRINGTON

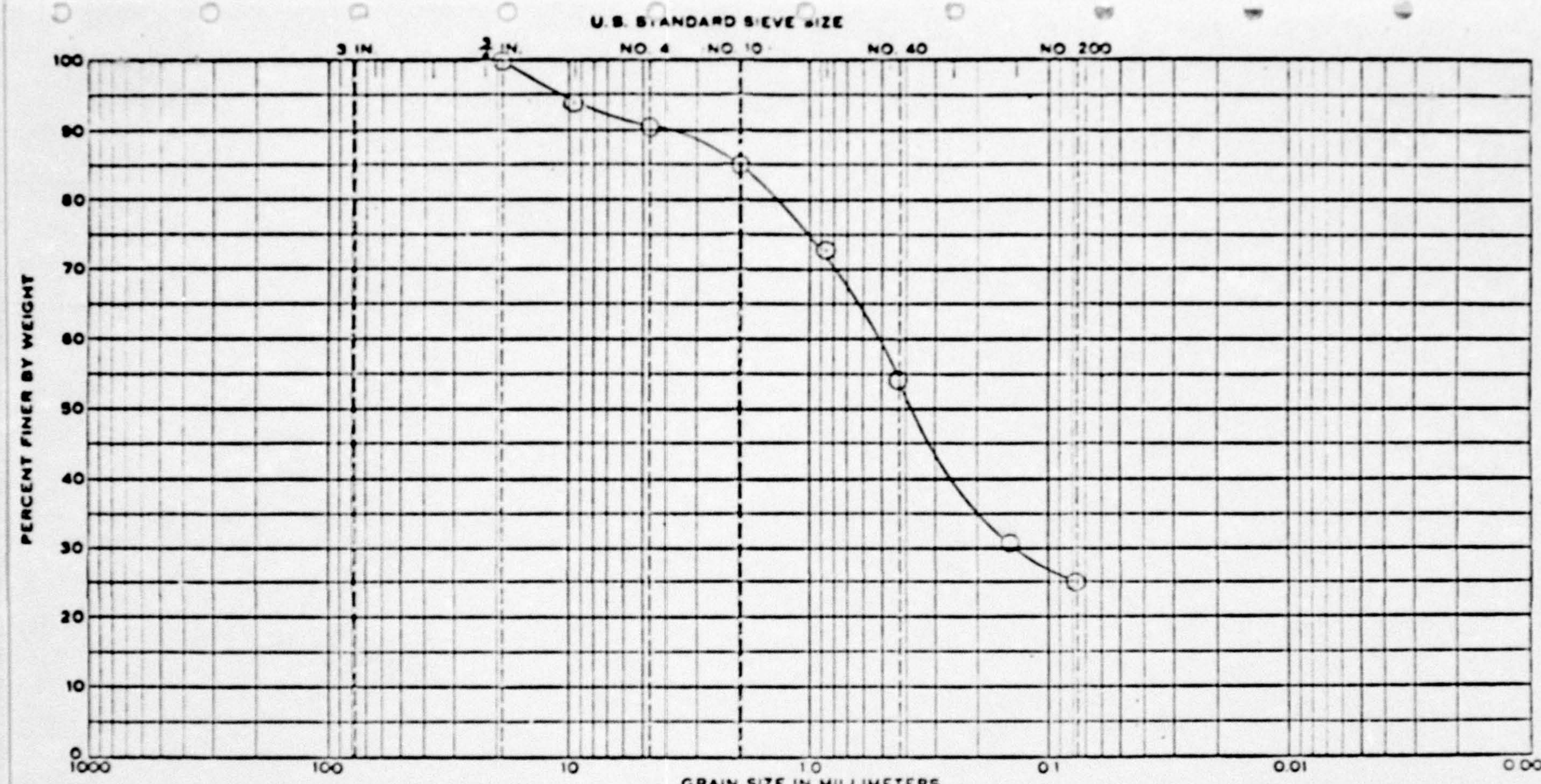
STRATA	DEPTH FT	ELEV 161.0±	BLOWS ON SAMPLE SPOON PER 6"	SYMBOL	IDENTIFICATION	REMARKS
					5" TOPSOIL	
		160	2+3+5	S	FINE TO COARSE CLAYEY SILTY SAND FILL, TRACE MICA, MOIST-BROWN (SM)	EMBANKMENT SHELL
	4.5	▼				
A			8+2+3	S	FINE SANDY SILTY CLAY, FILL WITH ROCK FRAGMENTS, MOIST-BROWN (CL)	
				3"		Tube Pressed 24" Recovery=24"
	10.5	150				
C			3+2+6	S	FINE TO COARSE SAND, TRACE SILT WITH ROOTS AND ORGANIC MATTER, WET-GRAY (SM)	STREAM DEPOSITS
	14.0					
D			16+100/6"	S	DISINTEGRATED ROCK, WET-GRAY (SM)	RESIDUAL SOIL
			72+28/4"	S		
	16.3		100/3"	S		

BORING TERMINATED @ 16.3 FT

WATER OBERSAVTION WELL INSTALLED 2/13/78

WATER LEVEL READINGS

DATE	TIME	DEPTHS
2/13/78	1:00 p.m.	5' 0"
2/24/78	1:00 p.m.	4' 7"
3/13/78	1:00 p.m.	2'9"



COBBLES	GRAVEL		SAND			SILT OR CLAY
	Coarse	Fine	Coarse	Medium	Fine	

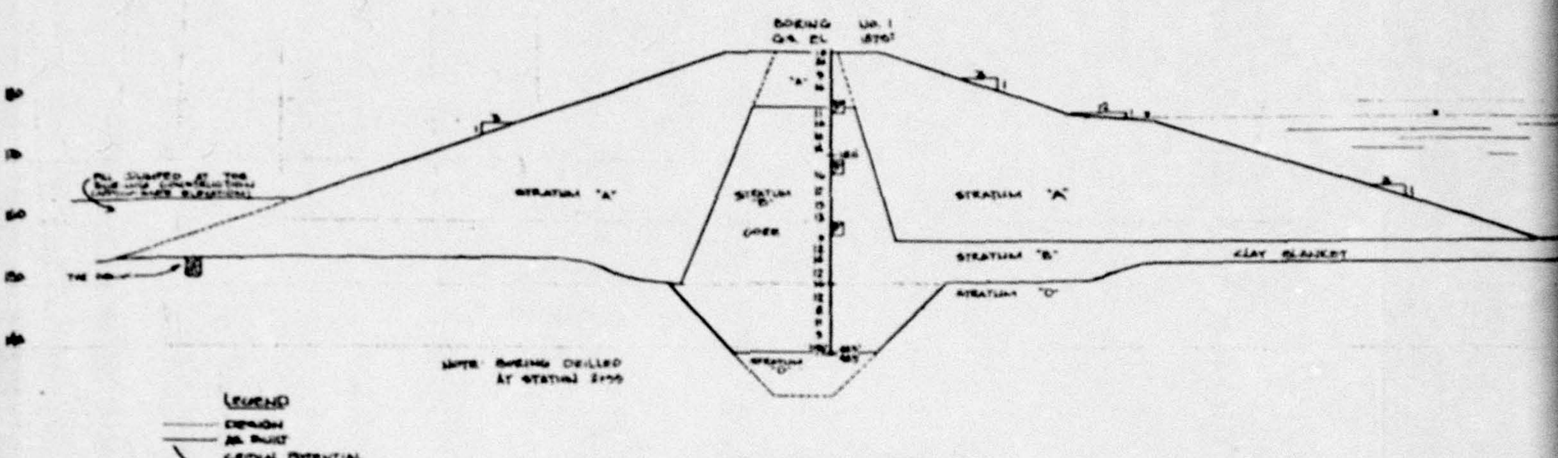
BORING	DEPTH	DESCRIPTION OF SOIL SAMPLE TESTED	CLASSIF.	M.C.	LL	PI
BULK #1	-	FINE TO COARSE SAND, FILL, SOME SILTY	SC	-	26	11
		CLAY, TRACE GRAVEL - BROWN				

SCHNABEL ENGINEERING ASSOCIATES

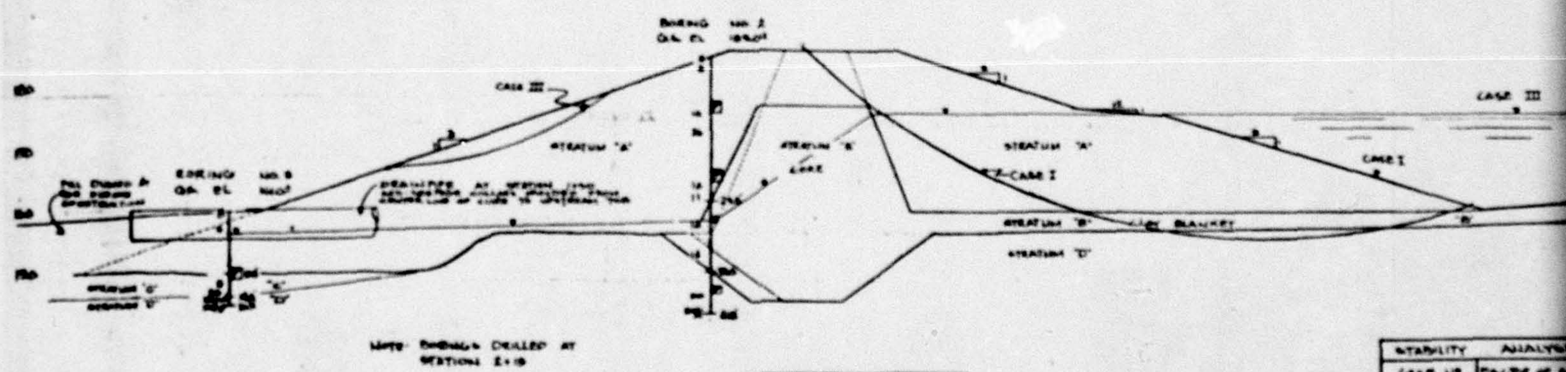
GRADATION CURVES

PROJECT: FALLING CREEK DAM
CHESTERFIELD CO. VIRGINIA

DATE: MARCH 8, 1978 CONTR. NO.: V780



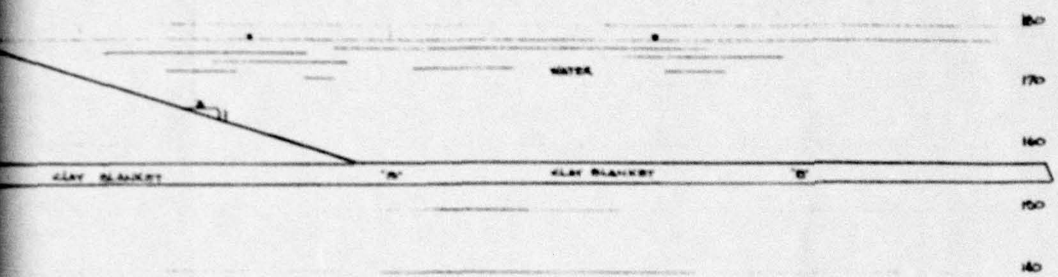
SECTION 3+00



SECTION 2+00

STABILITY ANALYSIS	
CASE NO.	FACTOR OF SA[illegible]
I	[illegible]
III	1.5

1



GENERAL NOTES

1. NUMBERS TO THE LEFT OF THE BORING COLUMN INDICATE NUMBER OF BLOWS REQUIRED TO DRIVE A 2 INCH O.D. 1⅜ INCH I.D. SAMPLING SPOON 12 INCHES USING A 140 LB HAMMER FALLING 30 INCHES.
2. ESTIMATED GROUNDWATER LEVELS INDICATED BY [illegible]; THESE LEVELS ARE ONLY ESTIMATED FROM AVAILABLE DATA AND MAY VARY WITH PRECIPITATION, POROSITY OF THE SOIL, SITE TOPOGRAPHY, ETC.
3. G.S. = GROUND SURFACE. ☑ = UNDISTURBED TUBE SAMPLE.
4. TEST BORINGS DRILLED BY MR. DVORAK AND INSPECTED BY SCHNABEL ENGINEERING ASSOCIATES.
5. THIS DRAWING CONTAINS INTERPRETATION OF TEST BORING DATA AND SHOULD NOT BE USED AS PART OF THE CONTRACT DOCUMENTS.
6. THESE PROFILES WERE DEVELOPED BY INTERPOLATION BETWEEN WIDELY SPACED BORINGS. ONLY AT THE BORING LOCATIONS SHOULD THEY BE CONSIDERED AS AN APPROXIMATELY ACCURATE REPRESENTATION AND THEN ONLY TO THE DEGREE IMPLIED BY THE NOTES ON THE BORING LOGS.

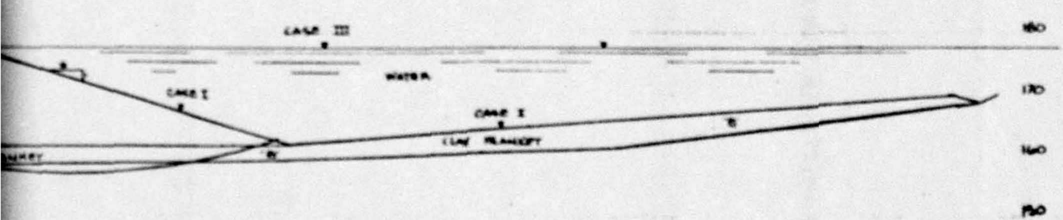
STRATA DESCRIPTIONS

STRATUM A: BROWN FINE TO COARSE SAND, FILL (SM), SOME CLAYEY SILT WITH BRICK FRAGMENTS; FINE TO COARSE SILTY CLAYEY SAND FILL [illegible] FINE TO MEDIUM SANDY SILTY CLAY, FILL (CL) WITH BRICK FRAGMENTS; LOOSE TO FIRM AND MEDIUM CONSISTENCY (N = [illegible] TO [illegible]).

STRATUM B: BROWN AND REDDISH BROWN FINE TO MEDIUM SANDY SILTY CLAY AND SANDY CLAY, FILL (CL-CH) WITH BRICK FRAGMENTS; STIFF TO VERY STIFF CONSISTENCY (N = 8 TO [illegible]).

STRATUM C: GRAY FINE TO COARSE SAND (SM), TRACE SILT WITH ROOTS AND ORGANIC MATTER; LOOSE (N=[illegible]).

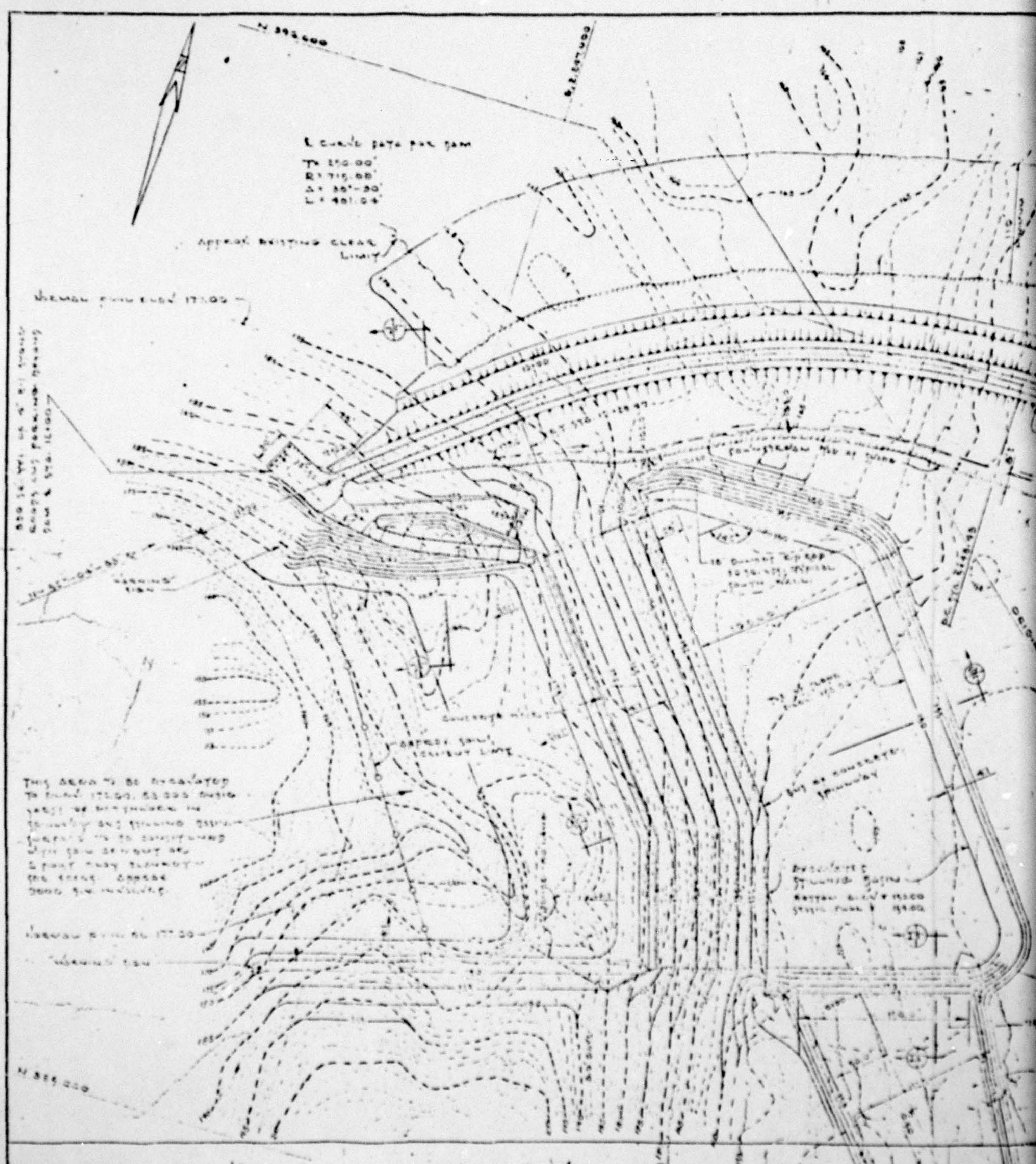
STRATUM D: GRAY DISINTEGRATED ROCK (SM), VERY COMPACT (N=[illegible])



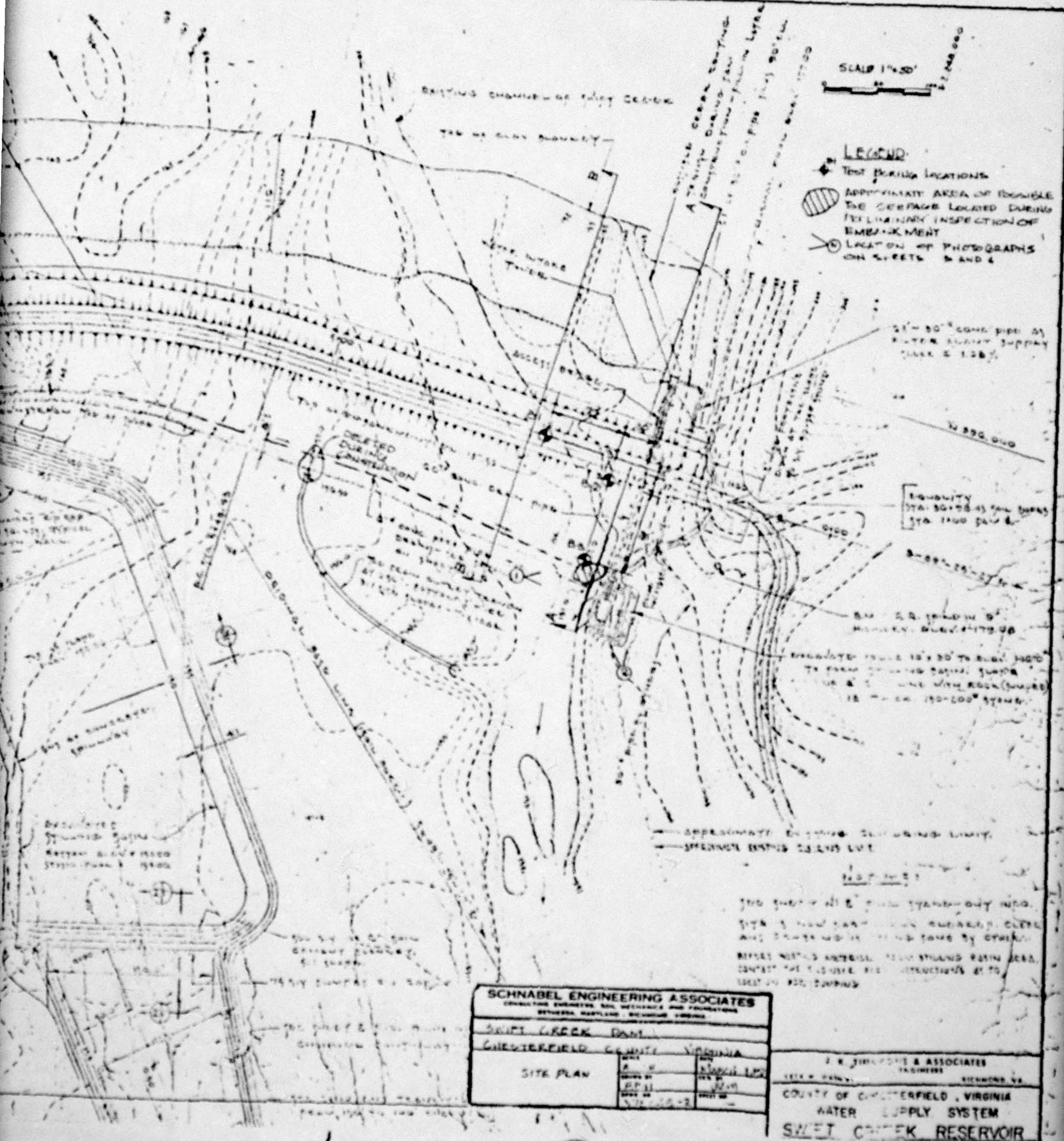
STABILITY ANALYSIS	
CASE №	FACTOR OF SAFETY
I	2.0
III	1.5

SCHNABEL ENGINEERING ASSOCIATES		
SWIFT CREEK RESERVOIR DAM		
CHESTERFIELD COUNTY, VIRGINIA		
ESTIMATED SUBSURFACE CONDITIONS	15 [illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	

1 2



1


SCALE 1"=50'
LEGEND
TEST BORING LOCATIONS
APPROXIMATE AREA OF POSSIBLE TOE SEEPAGE LOCATED DURING PRELIMINARY INSPECTION OF EMBANKMENT
LOCATION OF PHOTOGRAPHS ON SHEETS 3 AND 4
DELETED DURING CONSTRUCTION
SCHNABEL ENGINEERING ASSOCIATES
SWIFT CREEK DAM
CHESTERFIELD COUNTY VIRGINIA
SITE PLAN
ASSOCIATES
COUNTY OF CHESTERFIELD , VIRGINIA
WATER SUPPLY SYSTEM
SWIFT CREEK RESERVOIR

1

2

SCHNABEL ENGINEERING ASSOCIATES
P.C.
CONSULTING GEOTECHNICAL ENGINEERS

JAMES I. SCHNABEL P.E.
KAY E. MARTIN PH.D., P.E.
RAYMOND A. DESTEPHEN P.E.

ONE WEST CARY STREET
RICHMOND, VIRGINIA 23220
804-649-7035

September 14, 1979

J. K. Timmons & Associates
711 North Courthouse Road
Richmond, Virginia 23235

Attention: John Henson

Subject: Swift Creek Dam Inspection Report
(Our Contract V78045)

Gentlemen:

We have reviewed the Phase I Inspection Report prepared by Doward M. Martin and Associates for the Norfolk District Corps of Engineers. Based on this review we have the following comments:

1. The consultant indicates the dam contains a core wall, however, this should be referred to as a compacted clay core.

2. The consultant indicates that the phreatic surface through the dam is higher than that reported in our inspection report dated March 15, 1978. We monitored the water level side of the clay core in Boring B-2 by use of a water observation well on the downstream for a period of two weeks during our inspection. The water level was recorded at a depth of about 27 ft. Our analysis was based on the clay core functioning as designed. We obtained an additional water level reading in the water observation well in Boring B-2 on September 13, 1979. The water level was found to be 27'8" below the ground surface or 8" below the lowest level recorded in our inspection report. The clay core is functioning properly and no additional study is required.

3. Drained shear strength parameters for the predominantly sandy soils of Stratum A were assumed conservatively at $\phi' = 27^{o}$ and $c' = 0$ lbs/sq ft. Based on the conservative nature of the shear strength parameter and the minimum factor of safety of 1.5 obtained in the study for the steady seepage case we do not believe it is necessary to determine the drain strength parameters by additional laboratory testing.

4. The drain strength parameters for the clay core of Stratum B were also conservative values for the type of material in question. This can be seen if one compares the undrained values of ϕ which were recorded at 19 and 23^{o} with the assumed drained value of $\phi' = 20^{o}$. The ϕ' value should be higher than the ϕ value. Assuming the effective cohesion $c' = 0$ is certainly a conservative approach. Additional testing is not believed to be necessary.

PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 80,110,5
YC-MIN,YC-MAX,YC-INCR? 70,70,0
RAD-MIN,RAD-MAX,RAD-INCR? 35,50,5
NUMBER OF COLUMN LOADS? 0
EARTHQUAKE COEFFICIENT? 0

100, 125,5   105, 115,5
85, 115,5   90, 120,5   120,120,0
100,100,0   110,110,0   115,115,0
65,85,5   80, 90,5   80,95,5   85, 100,5

LINE NO.	LEFT ENDPT X	LEFT ENDPT Y	RIGHT ENDPT X	RIGHT ENDPT Y	WEIGHT	FRCTN ANGLE	COHESION FACTOR
1	0.00	50.00	53.00	50.00	125.00	14.00	750.00
2	53.00	50.00	83.00	41.00	125.00	14.00	750.00
3	83.00	41.00	97.00	40.00	125.00	14.00	750.00
4	97.00	40.00	149.00	24.00	-125.00	14.00	750.00
5	149.00	24.00	200.00	27.00	-125.00	19.00	1500.00
6	0.00	41.00	48.00	41.00	125.00	19.00	1500.00
7	48.00	41.00	49.00	39.00	125.00	19.00	1500.00
8	49.00	39.00	97.00	40.00	-125.00	14.00	750.00
9	0.00	20.00	21.00	21.00	-125.00	14.00	750.00
10	21.00	21.00	49.00	39.00	-125.00	14.00	750.00
11	49.00	39.00	56.00	23.00	-125.00	14.00	750.00
12	56.00	23.00	149.00	24.00	-125.00	14.00	750.00

----FAILURE CIRCLE---- XC	YC	RADIUS	-----------FORCES----------- COHESION	FRICTION	DRIVING	FACTOR OF SAFETY
80.00	70.00	35.00	39164.68	5999.27	6847.21	6.5960
80.00	70.00	40.00	50584.37	11240.58	12556.27	4.9238
80.00	70.00	45.00	64396.73	17708.50	18841.27	4.3577
80.00	70.00	50.00	77936.45	25466.85	25706.97	4.0224
85.00	70.00	35.00	36456.11	4582.30	5055.57	8.1175
85.00	70.00	40.00	49191.97	9619.74	11419.95	5.1499
85.00	70.00	45.00	60400.56	15724.07	18483.81	4.1184
85.00	70.00	50.00	74618.38	23134.00	26058.04	3.7513
90.00	70.00	35.00	32878.56	3361.25	3568.93	10.1543
90.00	70.00	40.00	46993.86	8009.21	9710.67	5.6642
90.00	70.00	45.00	59052.28	13911.46	17504.71	4.1682
90.00	70.00	50.00	70135.02	20900.71	25862.99	3.5199
95.00	70.00	35.00	28904.19	2353.17	2459.89	12.7068
95.00	70.00	40.00	43814.86	6534.94	8140.34	6.1852
95.00	70.00	45.00	57161.48	12081.49	15870.85	4.3629
95.00	70.00	50.00	68817.48	18859.38	24993.91	3.5079
100.00	70.00	35.00	24302.57	1572.69	1790.96	14.4477
100.00	70.00	40.00	40431.72	5220.02	6861.39	6.6534
100.00	70.00	45.00	54194.72	10351.18	14230.71	4.5357
100.00	70.00	50.00	67134.77	16792.80	23398.99	3.5868
105.00	70.00	35.00	20134.33	1029.86	1546.58	13.6845
105.00	70.00	40.00	36783.62	4073.34	5891.77	6.9346
105.00	70.00	45.00	51095.57	8759.92	12821.46	4.6684
105.00	70.00	50.00	64300.78	14812.76	21683.86	3.6465
110.00	70.00	35.00	16937.81	558.43	1144.84	15.2828
110.00	70.00	40.00	32773.81	3126.64	5280.29	6.7989
110.00	70.00	45.00	47836.41	7305.79	11641.84	4.7266
110.00	70.00	50.00	61370.84	12943.90	20148.31	3.6884

MINIMUM SAFETY FACTOR = 3.507929193E+00
FOR CENTER = (95.00, 70.00) AND RADIUS = 50.00

ANOTHER ANALYSIS ON THIS SLOPE? 1

ROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
C-MIN,XC-MAX,XC-INCR? 80,110,5
YC-MIN,YC-MAX,YC-INCR? 80,80,0
AD-MIN,RAD-MAX,RAD-INCR? 45,60,5
UMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
ARTHQUAKE COEFFICIENT? 0

----FAILURE CIRCLE----			------------FORCES------------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
80.00	80.00	45.00	43286.04	7442.09	8168.67	6.2101
80.00	80.00	50.00	55222.08	13335.32	14323.63	4.7863
80.00	80.00	55.00	71306.41	20810.44	21211.51	4.3428
80.00	80.00	60.00	85326.37	29534.65	28767.03	3.9928
85.00	80.00	45.00	41603.87	5865.64	6711.41	7.0730
85.00	80.00	50.00	53718.88	11593.06	13588.24	4.8065
85.00	80.00	55.00	67779.60	18569.74	21162.14	4.0804
85.00	80.00	60.00	81880.32	26870.67	29377.37	3.7019
90.00	80.00	45.00	38332.70	4348.27	4899.05	8.7121
90.00	80.00	50.00	52155.16	9814.04	12293.62	5.0408
90.00	80.00	55.00	63872.48	16402.53	20594.68	3.8979
90.00	80.00	60.00	78430.71	24329.88	29488.57	3.4848
95.00	80.00	45.00	34025.84	3049.46	3399.07	10.9075
95.00	80.00	50.00	49784.23	8038.36	10417.89	5.5503
95.00	80.00	55.00	62384.74	14395.40	19404.61	3.9568
95.00	80.00	60.00	73858.81	21862.90	29028.99	3.2975
100.00	80.00	45.00	29100.69	2007.36	2302.62	13.5099
100.00	80.00	50.00	46127.07	6407.80	8647.48	6.0752
100.00	80.00	55.00	60542.51	12367.36	17528.22	4.1596
100.00	80.00	60.00	72423.92	19615.25	27907.03	3.2981
105.00	80.00	45.00	23044.07	1259.90	1690.06	14.3806
105.00	80.00	50.00	42191.62	4978.94	7167.33	6.5813
105.00	80.00	55.00	57215.73	10443.10	15539.27	4.3541
105.00	80.00	60.00	70936.46	17342.37	26040.58	3.3900
110.00	80.00	45.00	19265.48	740.92	1312.37	15.2444
110.00	80.00	50.00	37884.47	3764.33	6008.80	6.9313
110.00	80.00	55.00	53717.82	8693.18	13781.81	4.5285
110.00	80.00	60.00	67813.01	15136.32	23875.49	3.4742

MINIMUM SAFETY FACTOR = 3.297452071E+00
FOR CENTER = (95.00, 80.00) AND RADIUS = 60.00

NOTHER ANALYSIS ON THIS SLOPE? 1

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PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 80,110,5
YC-MIN,YC-MAX,YC-INCR? 90,90,0
RAD-MIN,RAD-MAX,RAD-INCR? 55,70,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0
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----FAILURE CIRCLE----			-----------FORCES-----------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
80.00	90.00	55.00	46913.31	8724.86	9051.69	6.1467
80.00	90.00	60.00	62361.69	15536.97	15588.72	4.9971
80.00	90.00	65.00	77654.58	23709.74	22996.44	4.4078
80.00	90.00	70.00	92177.57	33311.44	31155.16	4.0279
85.00	90.00	55.00	45108.54	7085.59	7936.54	6.5764
85.00	90.00	60.00	57769.21	13372.18	15114.09	4.7070
85.00	90.00	65.00	73975.68	21216.51	23139.22	4.1139
85.00	90.00	70.00	88600.81	30387.96	31911.50	3.7287
90.00	90.00	55.00	43189.65	5422.94	6314.75	7.6983
90.00	90.00	60.00	56101.67	11499.01	14142.14	4.7801
90.00	90.00	65.00	70574.11	18884.03	22820.58	3.9201
90.00	90.00	70.00	85023.90	27573.55	32230.63	3.4935
95.00	90.00	55.00	38970.39	3844.37	4451.66	9.6177
95.00	90.00	60.00	54357.93	9595.82	12605.30	5.0736
95.00	90.00	65.00	66665.20	16559.12	21951.69	3.7912
95.00	90.00	70.00	81438.73	24881.72	32026.44	3.3198
100.00	90.00	55.00	33792.35	2538.29	2975.97	12.2080
100.00	90.00	60.00	51566.65	7697.22	10524.97	5.6308
100.00	90.00	65.00	65031.94	14406.97	20471.64	3.8804
100.00	90.00	70.00	76965.36	22260.84	31251.23	3.1751
105.00	90.00	55.00	27596.09	1552.22	1958.59	14.8823
105.00	90.00	60.00	47388.52	5990.75	8595.94	6.2098
105.00	90.00	65.00	63047.91	12233.70	18319.52	4.1094
105.00	90.00	70.00	75408.36	19856.34	29794.98	3.1973
110.00	90.00	55.00	21408.97	923.63	1448.12	15.4218
110.00	90.00	60.00	42835.23	4515.59	6981.21	6.7826
110.00	90.00	65.00	59340.63	10176.75	16052.70	4.3306
110.00	90.00	70.00	73802.43	17426.13	27635.42	3.3011

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   MINIMUM SAFETY FACTOR = 3.175108066E+00
   FOR CENTER = (  100.00,   90.00) AND RADIUS =   70.00

ANOTHER ANALYSIS ON THIS SLOPE? 1
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PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 250,250,0
YC-MIN,YC-MAX,YC-INCR? 130,130,0
RAD-MIN,RAD-MAX,RAD-INCR? 65,80,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0

----FAILURE CIRCLE----			-----------FORCES-----------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
250.00	130.00	65.00	0.00	7423.19	4963.22	1.4956
250.00	130.00	70.00	0.00	25565.67	15977.54	1.6001
250.00	130.00	75.00	0.00	49030.49	29143.40	1.6824
250.00	130.00	80.00	0.00	72860.44	43677.55	1.6681

MINIMUM SAFETY FACTOR = 1.495640819E+00
FOR CENTER = (250.00, 130.00) AND RADIUS = 65.00

ANOTHER ANALYSIS ON THIS SLOPE? 1

PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 240,240,0
YC-MIN,YC-MAX,YC-INCR? 130,130,0
RAD-MIN,RAD-MAX,RAD-INCR? 60,75,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0

----FAILURE CIRCLE----			-----------FORCES-----------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
240.00	130.00	60.00	0.00	3227.87	2181.52	1.4796
240.00	130.00	65.00	0.00	17781.49	11600.05	1.5329
240.00	130.00	70.00	0.00	39296.27	24787.16	1.5853
240.00	130.00	75.00	0.00	63679.03	39621.11	1.6072

MINIMUM SAFETY FACTOR = 1.479642063E+00
FOR CENTER = (240.00, 130.00) AND RADIUS = 60.00

ANOTHER ANALYSIS ON THIS SLOPE? 1

PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 220,230,10
YC-MIN,YC-MAX,YC-INCR? 130,130,0
RAD-MIN,RAD-MAX,RAD-INCR? 55,70,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0

----FAILURE CIRCLE----			-----------FORCES-----------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
220.00	130.00	55.00	0.00	6628.78	4411.24	1.5027
220.00	130.00	60.00	0.00	22493.99	14058.56	1.6000
220.00	130.00	65.00	0.00	43712.25	25033.21	1.7462
220.00	130.00	70.00	0.00	68118.80	36961.99	1.8429
230.00	130.00	55.00	0.00	501.77	343.37	1.4613
230.00	130.00	60.00	0.00	11644.11	7666.53	1.5188
230.00	130.00	65.00	0.00	30471.14	19352.09	1.5746
230.00	130.00	70.00	0.00	54709.69	32733.75	1.6714

MINIMUM SAFETY FACTOR = 1.461288218E+00
FOR CENTER = (230.00, 130.00) AND RADIUS = 55.00

ANOTHER ANALYSIS ON THIS SLOPE? 1

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PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 80,110,5
YC-MIN,YC-MAX,YC-INCR? 70,70,0
RAD-MIN,RAD-MAX,RAD-INCR? 50,60,2
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0
```

----FAILURE CIRCLE----			------------FORCES------------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
80.00	70.00	50.00	77936.45	25466.85	25706.97	4.0224
80.00	70.00	52.00	83281.89	28963.82	28622.43	3.9216
80.00	70.00	54.00	88598.17	32683.04	31641.88	3.8329
80.00	70.00	56.00	93890.35	36597.60	34742.57	3.7559
80.00	70.00	58.00	99162.41	40742.14	37932.51	3.6882
80.00	70.00	60.00	104417.50	45096.74	41223.48	3.6269
85.00	70.00	50.00	74618.38	23134.00	26058.04	3.7513
85.00	70.00	52.00	79980.53	26467.81	29255.20	3.6386
85.00	70.00	54.00	85311.27	30014.28	32517.90	3.5465
85.00	70.00	56.00	90616.07	33796.17	35879.80	3.4675
85.00	70.00	58.00	95899.21	37794.30	39340.01	3.3984
85.00	70.00	60.00	101164.09	41995.01	42877.70	3.3388
90.00	70.00	50.00	70135.02	20900.71	25962.99	3.5199
90.00	70.00	52.00	76670.42	24110.87	29334.72	3.4356
90.00	70.00	54.00	82016.91	27484.92	32875.87	3.3308
90.00	70.00	56.00	87335.36	31085.30	36524.68	3.2422
90.00	70.00	58.00	92630.42	34912.96	40235.74	3.1699
90.00	70.00	60.00	97905.80	38963.68	44046.05	3.1074
95.00	70.00	50.00	68817.48	18859.38	24993.91	3.5079
95.00	70.00	52.00	73232.12	21886.55	28780.04	3.3050
95.00	70.00	54.00	77627.26	25077.60	32642.04	3.1464
95.00	70.00	56.00	84041.31	28535.35	36556.78	3.0795
95.00	70.00	58.00	89349.76	32174.59	40562.09	2.9960
95.00	70.00	60.00	94636.85	36038.44	44650.59	2.9266
100.00	70.00	50.00	67134.77	16792.80	23398.99	3.5868
100.00	70.00	52.00	71907.04	19732.01	27500.61	3.3323
100.00	70.00	54.00	76323.05	22835.16	31678.62	3.1302
100.00	70.00	56.00	80719.92	26124.82	35922.51	2.9743
100.00	70.00	58.00	85100.84	29565.65	40230.71	2.8567
100.00	70.00	60.00	91351.37	33293.01	44603.42	2.7945
105.00	70.00	50.00	64200.78	14812.76	21663.86	3.6485
105.00	70.00	52.00	69422.28	17595.07	25711.67	3.3844
105.00	70.00	54.00	74481.89	20583.69	29986.95	3.1702
105.00	70.00	56.00	79408.60	23767.84	34502.68	2.9964
105.00	70.00	58.00	83807.59	27142.09	39135.07	2.8350
105.00	70.00	60.00	88190.84	30693.16	43834.60	2.7121
110.00	70.00	50.00	61370.84	12943.90	20148.31	3.6884
110.00	70.00	52.00	66578.22	15577.45	24066.94	3.4136
110.00	70.00	54.00	71708.16	18412.91	28238.57	3.1914
110.00	70.00	56.00	76776.90	21449.00	32662.92	3.0073
110.00	70.00	58.00	81796.37	24693.16	37390.51	2.8526
110.00	70.00	60.00	86775.56	28128.45	42239.15	2.7203

```
   MINIMUM SAFETY FACTOR = 2.712104405E+00
   FOR CENTER = ( 105.00,    70.00) AND RADIUS =    60.00

ANOTHER ANALYSIS ON THIS SLOPE? 0

ROCESSING   397 UNITS

RT
FF AT 18:06
ROCESSING     395 UNITS
```

```
PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 90,130,5
YC-MIN,YC-MAX,YC-INCR? 110,110,0
RAD-MIN,RAD-MAX,RAD-INCR? 80,90,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0
```

----FAILURE CIRCLE----			-----------FORCES-----------			FACTOR O
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
90.00	110.00	80.00	62993.99	14498.62	16535.72	4.666
90.00	110.00	85.00	81180.40	23383.85	25859.05	4.043
90.00	110.00	90.00	96994.19	33671.37	36131.51	3.616
95.00	110.00	80.00	61067.75	12466.25	15488.94	4.747
95.00	110.00	85.00	77205.14	20744.10	25381.68	3.859
95.00	110.00	90.00	93168.65	30541.75	36239.93	3.413
100.00	110.00	80.00	59045.11	10404.88	13934.22	4.984
100.00	110.00	85.00	72439.09	18123.38	24408.20	3.710
100.00	110.00	90.00	89330.21	27529.38	35853.86	3.259
105.00	110.00	80.00	56907.25	8323.02	11824.52	5.516
105.00	110.00	85.00	70574.91	15786.81	22878.56	3.774
105.00	110.00	90.00	85750.75	24685.37	34931.50	3.161
110.00	110.00	80.00	52435.02	6330.74	9419.03	6.239
110.00	110.00	85.00	68630.73	13426.84	20750.56	3.954
110.00	110.00	90.00	81626.13	21852.39	33420.36	3.096
115.00	110.00	80.00	46998.22	4624.55	7358.31	7.015
115.00	110.00	85.00	65771.37	11072.67	18020.42	4.264
115.00	110.00	90.00	79811.58	19216.51	31270.68	3.166
120.00	110.00	80.00	40844.63	3238.79	5697.30	7.737
120.00	110.00	85.00	61214.66	8911.87	15373.07	4.561
120.00	110.00	90.00	77928.96	16566.30	28427.16	3.324
125.00	110.00	80.00	34767.05	2213.93	4488.48	8.239
125.00	110.00	85.00	56315.89	7022.00	13029.81	4.861
125.00	110.00	90.00	114834.02	16957.05	25300.24	5.209
130.00	110.00	80.00	30661.50	1354.31	3190.60	10.034
130.00	110.00	85.00	50971.13	5420.90	11017.99	5.118
130.00	110.00	90.00	114489.79	14335.34	22249.93	5.789

```
     MINIMUM SAFETY FACTOR = 3.096272206E+00
     FOR CENTER = (  110.00,   110.00) AND RADIUS =    90.00

ANOTHER ANALYSIS ON THIS SLOPE? 1
```

```
PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 100,125,5
YC-MIN,YC-MAX,YC-INCR? 115,115,0
RAD-MIN,RAD-MAX,RAD-INCR? 80,95,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0
```

----FAILURE CIRCLE----			-----------FORCES-----------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
100.00	115.00	80.00	45261.27	4329.74	5234.30	9.4742
100.00	115.00	85.00	60526.34	11046.51	14561.31	4.9153
100.00	115.00	90.00	74131.11	18990.21	25138.49	3.7043
100.00	115.00	95.00	92006.70	28793.53	36733.29	3.2886
105.00	115.00	80.00	38810.62	2715.87	3329.84	12.4710
105.00	115.00	85.00	58347.07	8941.12	12585.05	5.3467
105.00	115.00	90.00	72230.00	16628.60	23720.84	3.7460
105.00	115.00	95.00	88091.42	25820.35	35902.26	3.1728
110.00	115.00	80.00	30872.03	1505.77	1952.44	16.5832
110.00	115.00	85.00	54791.19	6855.99	10120.47	6.0913
110.00	115.00	90.00	70248.04	14235.82	21724.14	3.8889
110.00	115.00	95.00	83425.61	22890.17	34502.88	3.0814
115.00	115.00	80.00	21747.29	799.55	1234.09	18.2701
115.00	115.00	85.00	49281.35	5023.47	7872.44	6.8981
115.00	115.00	90.00	68171.96	11828.19	19104.93	4.1874
115.00	115.00	95.00	81576.74	20221.23	32494.97	3.1327
120.00	115.00	80.00	16154.83	324.60	632.65	26.0484
120.00	115.00	85.00	43075.27	3519.80	6030.13	7.7270
120.00	115.00	90.00	63655.24	9542.57	16258.40	4.5022
120.00	115.00	95.00	79659.00	17536.55	29829.47	3.2584
125.00	115.00	80.00	5439.34	5.86	14.88	*******
125.00	115.00	85.00	35897.72	2390.84	4666.05	8.2058
125.00	115.00	90.00	58680.13	7522.64	13711.40	4.8283
125.00	115.00	95.00	119088.14	17901.83	26562.58	5.1573

```
     MINIMUM SAFETY FACTOR = 3.081359453E+00
     FOR CENTER = (  110.00,   115.00) AND RADIUS =    95.00

ANOTHER ANALYSIS ON THIS SLOPE? 1

PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 105,115,5
YC-MIN,YC-MAX,YC-INCR? 120,11_20,0
RAD-MIN,RAD-MAX,RAD-INCR? 85,100,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0
```

----FAILURE CIRCLE----			-----------FORCES-----------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
105.00	120.00	85.00	41036.79	3027.50	3708.94	11.8805
105.00	120.00	90.00	59740.29	9545.63	13262.55	5.2242
105.00	120.00	95.00	73833.43	17441.69	24471.95	3.7298
105.00	120.00	100.00	90647.63	26985.82	36785.19	3.1978
110.00	120.00	85.00	33168.00	1690.21	2155.40	16.1725
110.00	120.00	90.00	57134.14	7406.77	10857.49	5.9444
110.00	120.00	95.00	71815.42	15022.17	22597.42	3.8428
110.00	120.00	100.00	85172.14	23905.23	35486.01	3.0738
115.00	120.00	85.00	22624.50	871.86	1288.10	18.2411
115.00	120.00	90.00	51556.51	5446.48	8424.99	6.7659
115.00	120.00	95.00	69702.67	12589.74	20138.01	4.0864
115.00	120.00	100.00	83290.32	21210.97	33610.95	3.1091

```
     MINIMUM SAFETY FACTOR = 3.073813390E+00
```

```
PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 105,115,5
YC-MIN,YC-MAX,YC-INCR? 125,125,0
RAD-MIN,RAD-MAX,RAD-INCR? 90,105,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0

    ----FAILURE CIRCLE----        ------------FORCES------------       FACTOR OF
     XC        YC      RADIUS       COHESION    FRICTION     DRIVING      SAFETY
   105.00    125.00     90.00       43259.25     3362.89     4118.78     11.3194
   105.00    125.00     95.00       61090.86    10133.50    13869.13      5.1355
   105.00    125.00    100.00       75389.26    18235.39    25151.53      3.7224
   105.00    125.00    105.00       93144.37    28136.14    37579.92      3.2273
   110.00    125.00     90.00       35445.81     1901.29     2398.87     15.5686
   110.00    125.00     95.00       58694.50     7969.15    11591.65      5.7510
   110.00    125.00    100.00       73336.79    15792.67    23387.30      3.8110
   110.00    125.00    105.00       89405.26    25157.82    36376.00      3.1494
   115.00    125.00     90.00       24249.63      946.40     1342.29     18.7709
   115.00    125.00     95.00       53824.66     5898.05     9015.18      6.6247
   115.00    125.00    100.00       71189.11    13332.67    21056.76      4.0140
   115.00    125.00    105.00       84956.10    22175.22    34615.30      3.0949
    MINIMUM SAFETY FACTOR = 3.094912072E+00
      FOR CENTER = (  115.00,   125.00) AND RADIUS =  105.00

ANOTHER ANALYSIS ON THIS SLOPE? 0

PROCESSING   322 UNITS

OFF
OFF AT 13:15
PROCESSING...  322 UNITS
MIN...   21 PRIME    0 OFF-HR
```

```
LOAD **SLOPESTA
READY
1
5 DATA 12
10 DATA 1,0,50,53,50,125,14,750
20 DATA 2,53,50,83,41,125,14,750
30 DATA 3,83,41,97,40,125,14,750
40 DATA 4,97,40,149,24,-125,14,750
50 DATA 5,149,24,200,27,-125,19,1500
60 DATA 6,0,41,48,41,125,19,1500
70 DATA 7,48,41,49,39,125,19,1500
80 DATA 8,49,39,97,40,-125,14,750
90 DATA 0,20,21,21,-125,14,750
100 DATA 10,21,21,49,39,-125,14,750
110 DATA 11,49,39,56,23,-125,14,750
120 DATA 12,56,23,149,24,-125,14,750
RUN

SLOPESTA    17:45    02/27/78  MONDAY      I05


PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 80,110,5
YC-MIN,YC-MAX,YC-INCR? 70,70,0
RAD-MIN,RAD-MAX,RAD-INCR? 35,50,5
NUMBER OF COLUMN LOADS? 0
EARTHQUAKE COEFFICIENT? 0

PROGRAM LINE  1620:   END OF DATA

PROCESSING     3 UNITS

DIS 1620H
INVALID WITH RUN ONLY PROGRAM

BREAK

LOAD **SLOPESTA
READY
1
5 DATA 12
10 DATA 1,0,50,53,50,125,14,750
20 DATA 2,53,50,83,41,125,14,750
30 DATA 3,83,41,97,40,125,14,750
40 DATA 4,97,40,149,24,-125,14,750
50 DATA 5,149,24,200,27,-125,19,1500
60 DATA 6,0,41,48,41,125,19,1500
70 DATA 7,48,41,49,39,125,19,1500
80 DATA 8,49,39,97,40,-125,14,750
90 DATA 9,0,20,21,21,-125,14,750
100 DATA 10,21,21,49,39,-125,14,750
110 DATA 11,49,39,56,23,-125,14,750
120 DATA 12,56,23,149,24,-125,14,750
RUN

SLOPESTA    17:53    02/27/78  MONDAY      I05
```

SUDDEN DRAW...
CASE I

ASSUMES STRATUM B TO BOTTOM OF COORDINATE SYSTEM & ELIMINATE CIRCLES TH[AT] PENETRATE BELOW WHERE STRATUM D BEGINS.

```
5 DATA 12
10 DATA 1,0,50,53,50,125,14,750
20 DATA 2,53,50,83,41,125,14,750
30 DATA 3,83,41,97,40,125,14,750
40 DATA 4,97,40,149,24,-125,14,750
50 DATA 5,149,24,200,27,-125,19,1500
60 DATA 6,0,41,48,41,125,19,1500
70 DATA 7,48,41,49,39,125,19,1500
80 DATA 8,49,39,97,40,-125,14,750
90 DATA 9,0,20,21,21,-125,14,750
100 DATA 10,21,21,49,39,-125,14,750
110 DATA 11,49,39,56,23,-125,14,750
120 DATA 12,56,23,149,24,-125,14,750
RUN

SLOPESTA     13:00    02/28/78  TUESDAY     I05


PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 85,115,5
YC-MIN,YC-MAX,YC-INCR? 100,100,0
RAD-MIN,RAD-MAX,RAD-INCR? 65,80,5
NUMBER OF COLUMN LOADS? 0
EARTHQUAKE COEFFICIENT? 0
```

LINE NO.	LEFT ENDPT X	Y	RIGHT ENDPT X	Y	WEIGHT	FRCTN ANGLE	COHESION FACTOR
1	0.00	50.00	53.00	50.00	125.00	14.00	750.00
2	53.00	50.00	83.00	41.00	125.00	14.00	750.00
3	83.00	41.00	97.00	40.00	125.00	14.00	750.00
4	97.00	40.00	149.00	24.00	-125.00	14.00	750.00
5	149.00	24.00	200.00	27.00	-125.00	19.00	1500.00
6	0.00	41.00	48.00	41.00	125.00	19.00	1500.00
7	48.00	41.00	49.00	39.00	125.00	19.00	1500.00
8	49.00	39.00	97.00	40.00	-125.00	14.00	750.00
9	0.00	20.00	21.00	21.00	-125.00	14.00	750.00
10	21.00	21.00	49.00	39.00	-125.00	14.00	750.00
11	49.00	39.00	56.00	23.00	-125.00	14.00	750.00
12	56.00	23.00	149.00	24.00	-125.00	14.00	750.00

----FAILURE CIRCLE---- XC	YC	RADIUS	-----------FORCES----------- COHESION	FRICTION	DRIVING	FACTOR OF SAFETY
85.00	100.00	65.00	48261.95	8192.74	8791.83	6.4213
85.00	100.00	70.00	64315.34	15326.85	16248.01	4.9017
85.00	100.00	75.00	79735.53	23741.59	24671.69	4.1942
85.00	100.00	80.00	94887.39	33729.03	33934.53	3.7901
90.00	100.00	65.00	46232.41	6479.94	7463.51	7.0627
90.00	100.00	70.00	59690.30	13056.99	15499.61	4.6935
90.00	100.00	75.00	75908.45	21155.50	24524.90	3.9578
90.00	100.00	80.00	91185.89	30683.58	34383.06	3.5445
95.00	100.00	65.00	43796.86	4740.92	5616.68	8.6417
95.00	100.00	70.00	57850.30	11080.69	14244.35	4.8392
95.00	100.00	75.00	70593.28	18556.12	23877.34	3.7336
95.00	100.00	80.00	87478.18	27749.79	34357.52	3.3538
100.00	100.00	65.00	38414.47	3177.18	3784.35	10.9904
100.00	100.00	70.00	55916.23	9077.93	12429.33	5.2291
100.00	100.00	75.00	68875.53	16322.13	22690.03	3.7549
100.00	100.00	80.00	83756.29	24959.57	33808.52	3.2156
105.00	100.00	65.00	32102.89	1939.70	2397.51	14.1991
105.00	100.00	70.00	52436.64	7104.23	10150.64	5.8657

95.00	100.00	80.00	[illegible]	[illegible]	[illegible]	[illegible]
100.00	100.00	65.00	38414.47	3177.18	3784.35	10.9904
100.00	100.00	70.00	55916.23	9077.93	12429.33	5.2291
100.00	100.00	75.00	68875.53	16322.13	22690.03	3.7549
100.00	100.00	80.00	83756.29	24959.57	33808.52	3.2156
105.00	100.00	65.00	32102.89	1939.70	2397.51	14.1991
105.00	100.00	70.00	52436.64	7104.23	10150.64	5.8657
105.00	100.00	75.00	67090.55	14052.91	20887.95	3.8847
105.00	100.00	80.00	79533.74	22225.58	32656.38	3.1161
110.00	100.00	65.00	23787.93	1102.77	1563.86	15.9162
110.00	100.00	70.00	47675.33	5369.03	8125.04	6.5205
110.00	100.00	75.00	64771.57	11771.94	18438.56	4.1513
110.00	100.00	80.00	77850.34	19694.76	30867.03	3.1602
115.00	100.00	65.00	19007.56	577.17	1043.51	18.7682
115.00	100.00	70.00	42403.11	3909.92	6448.46	7.1820
115.00	100.00	75.00	60657.28	9640.56	15950.63	4.4072
115.00	100.00	80.00	76108.93	17143.16	28371.09	3.2869

```
    MINIMUM SAFETY FACTOR = 3.116062653E+00
    FOR CENTER = (  105.00,   100.00) AND RADIUS =   80.00

ANOTHER ANALYSIS ON THIS SLOPE? 1
```

AD-A075 319 MARTIN (DEWARD M) AND ASSOCIATES INC WILLIAMSBURG VA F/G 13/2
NATIONAL DAM SAFETY PROGRAM. SWIFT CREEK RESERVOIR DAM (INVENTO--ETC(U)
AUG 79 P SEILER DACW65-78-D-0015

UNCLASSIFIED NL

2 OF 2
AD-
A075319

END
DATE
FILMED
11-79
DDC

5. The consultant's comments with respect to the failure surface being located in disintegrated rock for the most critical slip circle evaluated for the rapid drawdown case is certainly valid. However, this is a drafting error. The circle used in the analysis did not penetrate the disintegrated rock. We have enclosed copies of our worksheets and computer printout for the stability analysis which illustrates the procedure utilized. The analysis assumed that Stratum D did not exist and all circles which penetrated below the assumed level of Stratum D were eliminated from consideration.

In summary, we do not believe additional testing and evaluation with respect to stability of the dam are necessary. If you have any questions, please contact us.

Very truly yours,

SCHNABEL ENGINEERING ASSOCIATES, P.C.

Raymond A. DeStephen

Raymond A. DeStephen, P.E.
Commonwealth of Virginia

RAD:bls

Enclosures

```
PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 65,80,5
YC-MIN,YC-MAX,YC-INCR? 135,135,0
RAD-MIN,RAD-MAX,RAD-INCR? 65,80,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0

    ----FAILURE CIRCLE----          ------------FORCES------------      FACTOR OF
   XC         YC       RADIUS      COHESION   FRICTION   DRIVING         SAFETY
  65.00     135.00      65.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  65.00     135.00      70.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  65.00     135.00      75.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  65.00     135.00      80.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  70.00     135.00      65.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  70.00     135.00      70.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  70.00     135.00      75.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  70.00     135.00      80.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  75.00     135.00      65.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  75.00     135.00      70.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  75.00     135.00      75.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  75.00     135.00      80.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  80.00     135.00      65.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  80.00     135.00      70.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  80.00     135.00      75.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
  80.00     135.00      80.00 *CIRCLE INTERSECTS SLOPE ONLY ONCE
    MINIMUM SAFETY FACTOR = 2.047387087E+00
    FOR CENTER = (   65.00,   135.00) AND RADIUS =    65.00

ANOTHER ANALYSIS ON THIS SLOPE? 1

PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 325,____235,225,10
YC-MIN,YC-MAX,YC-INCR? 135,135,0
RAD-MIN,RAD-MAX,RAD-INCR? 55,80,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0

    ----FAILURE CIRCLE----          ------------FORCES------------      FACTOR OF
   XC         YC       RADIUS      COHESION   FRICTION   DRIVING         SAFETY
 235.00     135.00      55.00 *CIRCLE DOES NOT INTERSECT SLOPE
 235.00     135.00      60.00 *CIRCLE DOES NOT INTERSECT SLOPE
 235.00     135.00      65.00          0.00    8091.10    5400.17        1.4983
 235.00     135.00      70.00          0.00   25993.45   16792.41        1.5479
 235.00     135.00      75.00          0.00   50079.13   30969.12        1.6171
 235.00     135.00      80.00          0.00   75416.31   45581.38        1.6545
    MINIMUM SAFETY FACTOR = 1.498304337E+00
    FOR CENTER = (  235.00,   135.00) AND RADIUS =    65.00

ANOTHER ANALYSIS ON THIS SLOPE? 1
```

PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 230 240____,240,10
YC-MIN,YC-MAX,YC-INCR? 120,120,0
RAD-MIN,RAD-MAX,RAD-INCR? 50,65,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0

----FAILURE CIRCLE----			------------FORCES------------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
230.00	120.00	50.00	0.00	9074.41	5952.15	1.5246
230.00	120.00	55.00	0.00	25704.35	16176.11	1.5890
230.00	120.00	60.00	0.00	47950.89	29010.34	1.6529
230.00	120.00	65.00	0.00	70732.84	42770.51	1.6538
240.00	120.00	50.00	0.00	1976.33	1337.82	1.4773
240.00	120.00	55.00	0.00	14479.18	9396.98	1.5409
240.00	120.00	60.00	0.00	33711.90	21061.40	1.6006
240.00	120.00	65.00	0.00	55716.70	34562.30	1.6121

MINIMUM SAFETY FACTOR = 1.477270963E+00
FOR CENTER = (240.00, 120.00) AND RADIUS = 50.00

ANOTHER ANALYSIS ON THIS SLOPE? 1

PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 220,220,0
YC-MIN,YC-MAX,YC-INCR? 120,120,0
RAD-MIN,RAD-MAX,RAD-INCR? 45,60,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0

----FAILURE CIRCLE----			------------FORCES------------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
220.00	120.00	45.00	0.00	4774.78	3171.95	1.5053
220.00	120.00	50.00	0.00	18732.11	11884.24	1.5762
220.00	120.00	55.00	0.00	38245.12	22641.50	1.6892
220.00	120.00	60.00	0.00	62190.63	34149.14	1.8211

MINIMUM SAFETY FACTOR = 1.505315723E+00
FOR CENTER = (220.00, 120.00) AND RADIUS = 45.00

ANOTHER ANALYSIS ON THIS SLOPE? 1

PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 200,210,10
YC-MIN,YC-MAX,YC-INCR? 120,120,0
RAD-MIN,RAD-MAX,RAD-INCR? 40,60,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0

----FAILURE CIRCLE----			------------FORCES------------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
200.00	120.00	40.00	0.00	7325.31	4193.22	1.7469
200.00	120.00	45.00	0.00	20691.45	10207.41	2.0271
200.00	120.00	50.00	0.00	37124.01	17276.14	2.1489
200.00	120.00	55.00	0.00	56278.65	25206.16	2.2327
200.00	120.00	60.00	0.00	74283.92	33951.07	2.1880
210.00	120.00	40.00	0.00	1659.48	1119.56	1.4823
210.00	120.00	45.00	0.00	12651.88	7904.01	1.6007
210.00	120.00	50.00	0.00	29178.83	16269.65	1.7935
210.00	120.00	55.00	0.00	49267.97	25519.38	1.9306
210.00	120.00	60.00	0.00	71578.78	35553.92	2.0132

```
PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 230,230,0
YC-MIN,YC-MAX,YC-INCR? 100,100,0
RAD-MIN,RAD-MAX,RAD-INCR? 30,45,5
DBMFBPBOFADDEDYNCHANGED OR DELETED?
                                        EARTHQUAKE COEFFICIENT? 0
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----FAILURE CIRCLE----			-----------FORCES------------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
230.00	100.00	30.00	0.00	4813.02	3110.91	1.547
230.00	100.00	35.00	0.00	16819.17	10177.39	1.652
230.00	100.00	40.00	0.00	33888.59	19422.79	1.744
230.00	100.00	45.00	0.00	52073.95	30416.03	1.712

```
    MINIMUM SAFETY FACTOR = 1.547142421E+00
    FOR CENTER = (  230.00,   100.00) AND RADIUS =   30.00

ANOTHER ANALYSIS ON THIS SLOPE? 0

PROCESSING   276 UNITS

OFF
OFF AT 16:00
PROCESSING...  276 UNITS
MIN...    36 PRIME     0 OFF-HR
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PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 230,240,10
YC-MIN,YC-MAX,YC-INCR? 110,110,0
RAD-MIN,RAD-MAX,RAD-INCR? 40,55,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0

----FAILURE CIRCLE----			------------FORCES------------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
230.00	110.00	40.00	0.00	6799.68	4435.47	1.5330
230.00	110.00	45.00	0.00	21162.56	13119.66	1.6130
230.00	110.00	50.00	0.00	40899.65	24265.22	1.6855
230.00	110.00	55.00	0.00	61585.37	37344.32	1.6491
240.00	110.00	40.00	0.00	1024.54	695.26	1.4736
240.00	110.00	45.00	0.00	11462.39	7383.92	1.5523
240.00	110.00	50.00	0.00	28359.36	17462.80	1.6240
240.00	110.00	55.00	0.00	47822.62	29315.16	1.6313

MINIMUM SAFETY FACTOR = 1.473619315E+00
FOR CENTER = (240.00, 110.00) AND RADIUS = 40.00

ANOTHER ANALYSIS ON THIS SLOPE? 1

PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 240,250,10
YC-MIN,YC-MAX,YC-INCR? 100,100,0
RAD-MIN,RAD-MAX,RAD-INCR? 35,50,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETOUU
EARTHQUAKE COEFFICIENT? 0

----FAILURE CIRCLE----			------------FORCES------------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
240.00	100.00	35.00	0.00	8719.47	5551.11	1.5708
240.00	100.00	40.00	0.00	23192.92	13951.39	1.6624
240.00	100.00	45.00	0.00	40048.66	24056.79	1.6648
240.00	100.00	50.00	0.00	57749.26	34988.59	1.6505
250.00	100.00	35.00	0.00	[illegible]	[illegible]	1.4992
250.00	100.00	40.00	0.00	13929.61	8450.08	1.6485
250.00	100.00	45.00	0.00	29935.18	16938.56	1.7673
250.00	100.00	50.00	0.00	46656.28	26470.99	1.7625

MINIMUM SAFETY FACTOR = 1.499210073E+00
FOR CENTER = (250.00, 100.00) AND RADIUS = 35.00

ANOTHER ANALYSIS ON THIS SLOPE? 1

100

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PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 240,240,0
YC-MIN,YC-MAX,YC-INCR? 140,140,0
RAD-MIN,RAD-MAX,RAD-INCR? 70,85,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0
```

----FAILURE CIRCLE----			-----------FORCES-----------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
240.00	140.00	70.00	0.00	4780.36	3227.28	1.4812
240.00	140.00	75.00	0.00	21368.77	13992.17	1.5272
240.00	140.00	80.00	0.00	45086.05	28522.79	1.5807
240.00	140.00	85.00	0.00	71339.32	43595.81	1.6364

```
    MINIMUM SAFETY FACTOR = 1.481236005E+00
    FOR CENTER = (  240.00,   140.00) AND RADIUS =   70.00

ANOTHER ANALYSIS ON THIS SLOPE? 1


PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 240,240,0
YC-MIN,YC-MAX,YC-INCR? 135,135,0
RAD-MIN,RAD-MAX,RAD-INCR? 65,80,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0
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----FAILURE CIRCLE----			-----------FORCES-----------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
240.00	135.00	65.00	0.00	3966.75	2679.33	1.4805
240.00	135.00	70.00	0.00	19537.68	12770.85	1.5299
240.00	135.00	75.00	0.00	42188.90	26700.43	1.5801
240.00	135.00	80.00	0.00	67556.94	41732.50	1.6188

```
    MINIMUM SAFETY FACTOR = 1.480499743E+00
    FOR CENTER = (  240.00,   135.00) AND RADIUS =   65.00

ANOTHER ANALYSIS ON THIS SLOPE? 1


PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 250,250,0
YC-MIN,YC-MAX,YC-INCR? 110,110,0
RAD-MIN,RAD-MAX,RAD-INCR? 45,60,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0
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----FAILURE CIRCLE----			-----------FORCES-----------			FACTOR OF
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
250.00	110.00	45.00	0.00	3807.76	2542.61	1.4976
250.00	110.00	50.00	0.00	17549.34	10782.16	1.6276
250.00	110.00	55.00	0.00	36133.53	20883.36	1.7303
250.00	110.00	60.00	0.00	55265.52	32127.72	1.7202

```
    MINIMUM SAFETY FACTOR = 1.497580282E+00
    FOR CENTER = (  250.00,   110.00) AND RADIUS =   45.00

ANOTHER ANALYSIS ON THIS SLOPE? 1
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PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 220,230,10
YC-MIN,YC-MAX,YC-INCR? 130,__5,135,0
RAD-MIN,RAD-MAX,RAD-INCR? 60,75,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0
EARTHQUAKE COEFFICIENT? 0

   ----FAILURE CIRCLE----        ------------FORCES------------      FACTOR OF
   XC        YC       RADIUS      COHESION    FRICTION    DRIVING      SAFETY
 220.00    135.00     60.00         0.00      7664.14     5103.24      1.5018
 220.00    135.00     65.00         0.00     24270.86    14878.75      1.6312
 220.00    135.00     70.00         0.00     46285.85    25982.52      1.7814
 220.00    135.00     75.00         0.00     70812.49    38092.81      1.8589
 230.00    135.00     60.00         0.00       862.54      589.24      1.4638
 230.00    135.00     65.00         0.00     13036.20     8594.88      1.5167
 230.00    135.00     70.00         0.00     32831.74    20739.07      1.5831
 230.00    135.00     75.00         0.00     57933.32    34238.09      1.6921
     MINIMUM SAFETY FACTOR = 1.463802568E+00
     FOR CENTER = (  230.00,   135.00) AND RADIUS =    60.00

ANOTHER ANALYSIS ON THIS SLOPE? 1


PROBLEM MODE (1=FIXED CIRCLE, 2=VARIABLE CIRCLE)? 2
XC-MIN,XC-MAX,XC-INCR? 210,230,10
YC-MIN,YC-MAX,YC-INCR? 140,140,0
RAD-MIN,RAD-MAX,RAD-INCR? 65,80,5
NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0

    ----FAILURE CIRCLE----        ------------FORCES------------      FACTOR OF
    XC        YC       RADIUS      COHESION    FRICTION    DRIVING      SAFETY
  210.00    140.00     65.00         0.00     17645.68     9784.59      1.8034
  210.00    140.00     70.00         0.00     36492.95    18597.83      1.9622
  210.00    140.00     75.00         0.00     58020.94    28645.66      2.0255
  210.00    140.00     80.00         0.00     82996.32    39711.90      2.0900
  220.00    140.00     65.00         0.00      8742.12     5791.38      1.5095
  220.00    140.00     70.00         0.00     25996.95    15594.26      1.6671
  220.00    140.00     75.00         0.00     48462.70    26806.32      1.8079
  220.00    140.00     80.00         0.00     73376.39    39099.77      1.8766
  230.00    140.00     65.00         0.00      1305.69      890.76      1.4658
  230.00    140.00     70.00         0.00     14504.76     9574.95      1.5149
  230.00    140.00     75.00         0.00     35131.93    21946.33      1.6008
  230.00    140.00     80.00         0.00     61054.28    35557.99      1.7170
      MINIMUM SAFETY FACTOR = 1.465821161E+00
      FOR CENTER = (  230.00,   140.00) AND RADIUS =    65.00

  ANOTHER ANALYSIS ON THIS SLOPE?
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[illegible]

XC-MIN,XC-MAX,XC-INCR? 200,210,10

YC-MIN,YC-MAX,YC-INCR? 130,130,0

RAD-MIN,RAD-MAX,RAD-INCR? 50,70,5

NUMBER OF COLUMN LOADS TO BE ADDED, CHANGED OR DELETED? 0

EARTHQUAKE COEFFICIENT? 0

----FAILURE	CIRCLE----		-----------	FORCES------	------------	FACTOR O
XC	YC	RADIUS	COHESION	FRICTION	DRIVING	SAFETY
200.00	130.00	50.00	0.00	8831.75	4605.69	1.917
200.00	130.00	55.00	0.00	23539.28	10835.31	2.172
200.00	130.00	60.00	0.00	40616.59	18295.10	2.220
200.00	130.00	65.00	0.00	61154.47	26772.77	2.284
200.00	130.00	70.00	0.00	80049.29	36137.61	2.215
210.00	130.00	50.00	0.00	2810.12	1893.71	1.483
210.00	130.00	55.00	0.00	15257.13	9013.17	1.692
210.00	130.00	60.00	0.00	33324.92	17621.64	1.891
210.00	130.00	65.00	0.00	53896.80	27307.47	1.973
210.00	130.00	70.00	0.00	77572.05	37888.32	2.047

MINIMUM SAFETY FACTOR = 1.483926566E+00

FOR CENTER = (210.00, 130.00) AND RADIUS = 50.00

ANOTHER ANALYSIS ON THIS SLOPE?

APPENDIX V

REFERENCES

LIST OF REFERENCES

1. Recommended Guidelines for Safety Inspection of Dams, Department of the Army, Office of the Chief of Engineers, Washington, D.C. 20314.

2. HEC-1 Flood Hydrograph Package, Hdyrologic Engineering Center, U S Army Corps of Engineers, Davis, California, 1973

3. U S Weather Bureau and U S Army Corps of Engineers, "Seasonal Variations of Probable Maximum Precipitation East of the 105th Median for Areas from 10 to 1,000 Square Miles and Durations of 6, 12, 24 and 48 Hours", Hydrometeorological Report No. 33, Washington, D.C., April 1956.